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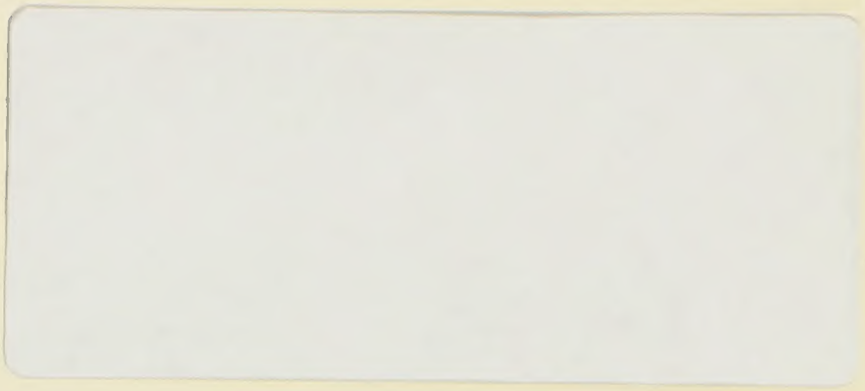

CENSUS METHODS FOR WILD HORSES AND BURROS

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INTRODUCTION

Extensive literature is available on aerial censusing of a number of wildlife species. Sources of variation in probability of sighting associated with aerial censusing have been examined by many investigators, including Petrides (1953), Fuller (1953), Banfield et al. (1955), Gilbert and Grieb (1957), Stewart et al. (1958), Erickson and Siniff (1963), Bergerud (1963), Goddard (1967), Graham and Bell (1969), Watson et al. (1969), Caughley (1974), LeResche and Rausch (1974), Caughley et al. (1976), Rice and Harder (1977), and Beasom (1979). Factors such as air speed, altitude, type of aircraft, observer experience and fatigue, sun position, weather, terrain, vegetation, age and behavior of the animal, group size and distribution have been identified as contributing to and causing variation in the probability of sighting.

Little information is available, however, on aerial censusing of wild horses. The only published report on wild horse censusing was prepared by Frei et al. (1979). They attempted to evaluate the effects of aircraft type and observer experience on the accuracy of aerial censusing. Their conclusions indicated that the differences between 3 types of aircraft were not significant but observer experience did have a significant effect on census outcome.

This research was undertaken to further evaluate aerial censusing of wild horses. The objectives outlined in the original proposal and subsequent contract were:

1. Select 2 to 3 western U.S. regions in which to evaluate census approaches.
2. Test accuracy and precision of these approaches:
   a. complete counts
   b. mark-resight estimation
   c. strip-transect estimation
3. Develop a set of criteria by which to choose the appropriate approach for a given area with particular habitat characteristics.
4. Investigate the effect of such variables as weather, vegetation, terrain, herd size, and horse distribution on probability of observation.
5. Prepare reports and census manual.

Several BLM districts in Nevada, Oregon and California were visited by project personnel during August 1980 to examine potential study sites suggested by BLM. Three areas were selected: Beatys Butte Herd Management Area (Lakeview District, Oregon), Pah Rah Mustang Area and Pine Nut Mountains (both Carson City District, Nevada). An additional study area, the Chain Lakes Herd Area (Rawlins District, Wyoming) was added in 1981. Burro censusing was observed on the Black Mountains in the Phoenix District, Arizona.

Color and radio collars were placed on wild horses on the Pah Rah and Pine Nut areas during October and November 1980, and in March 1981. Census trials were initiated on these areas and the Beatys Butte area during January 1981 and continued through September 1981. Census flights were conducted on the Chain Lakes area during November, 1981.

The authors would like to acknowledge the assistance of a number of Bureau of Land Management field personnel. The staff of the Carson City District provided invaluable assistance in capture and collaring of horses. T. Owen, T. Reuwsaat, P. Anderson, D. Pomi, B. Stewart were extremely helpful and supportive throughout the project. M. Frei, Nevada State Office also provided valuable assistance. A. K. Majors and B. Whitaker of the Lakeview District, Oregon provided assistance with field studies in Oregon. J. Winnepenninky was helpful in conducting flights in the Rawlins District, Wyoming. K. Grissom, Phoenix District, Arizona, graciously allowed us to observe burro censusing in the Black Mountains.

STUDY AREAS

Pah Rah Mustang Area

The Pah Rah Mustang Area (Figure 1) is located in northwestern Nevada in BLM's Carson City District. The area contains 184,000 acres which are mostly covered by sagebrush with occasional juniper. Spanish Springs Peak, with an elevation of 8500 feet, is 3500 feet above the canyon floor. There are numerous other smaller peaks and canyons in this rugged mountainous area. The area is well deliniated by fences and roads. This area has been censused 3 times by BLM personnel since 1971. The results of these censuses are given in Table 1.

Pine Nut Mountains

This area is also located in BLM's Carson City District. The bulk of this 322,000 acre mountainous area (Figure 2) is covered by pinyon-juniper. There are large open sagebrush areas at some of the lower and higher elevations. Several high peaks are present, with the highest being Mt. Siegel whose elevation is over 9500 feet. The area is isolated by a river, fences and roads. This area has been censused 2 times by BLM personnel since 1971 and these results are presented in Table 1.

Beatys Butte HMA

This area encompasses 396,000 acres and is located in south-central Oregon in BLM's Lakeview District (Figure 3). The area has rolling topography with maximum relief being approximately 1500 feet. It

Figure 1. Location of Pah Rah Mustang Area, Nevada.

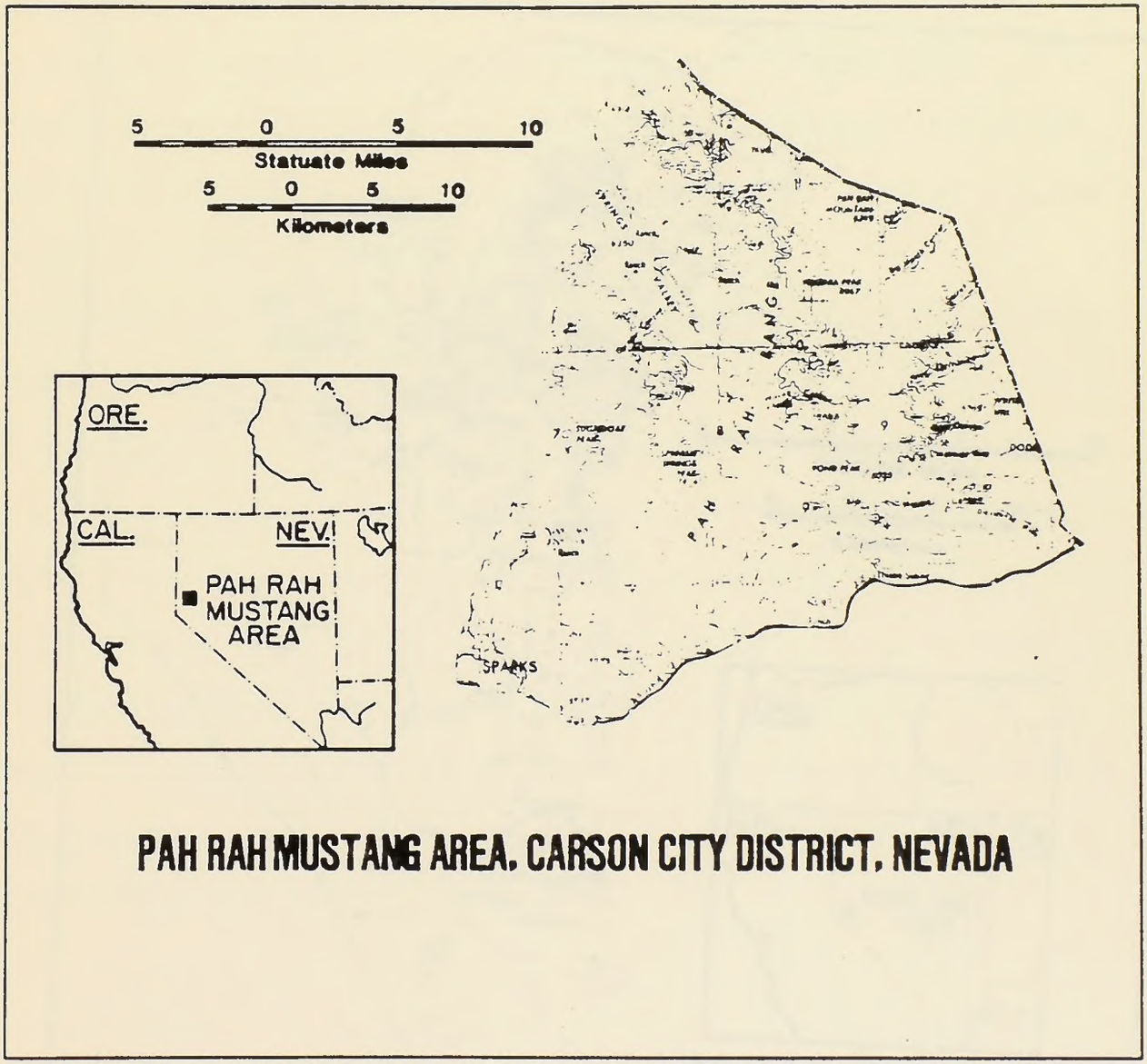
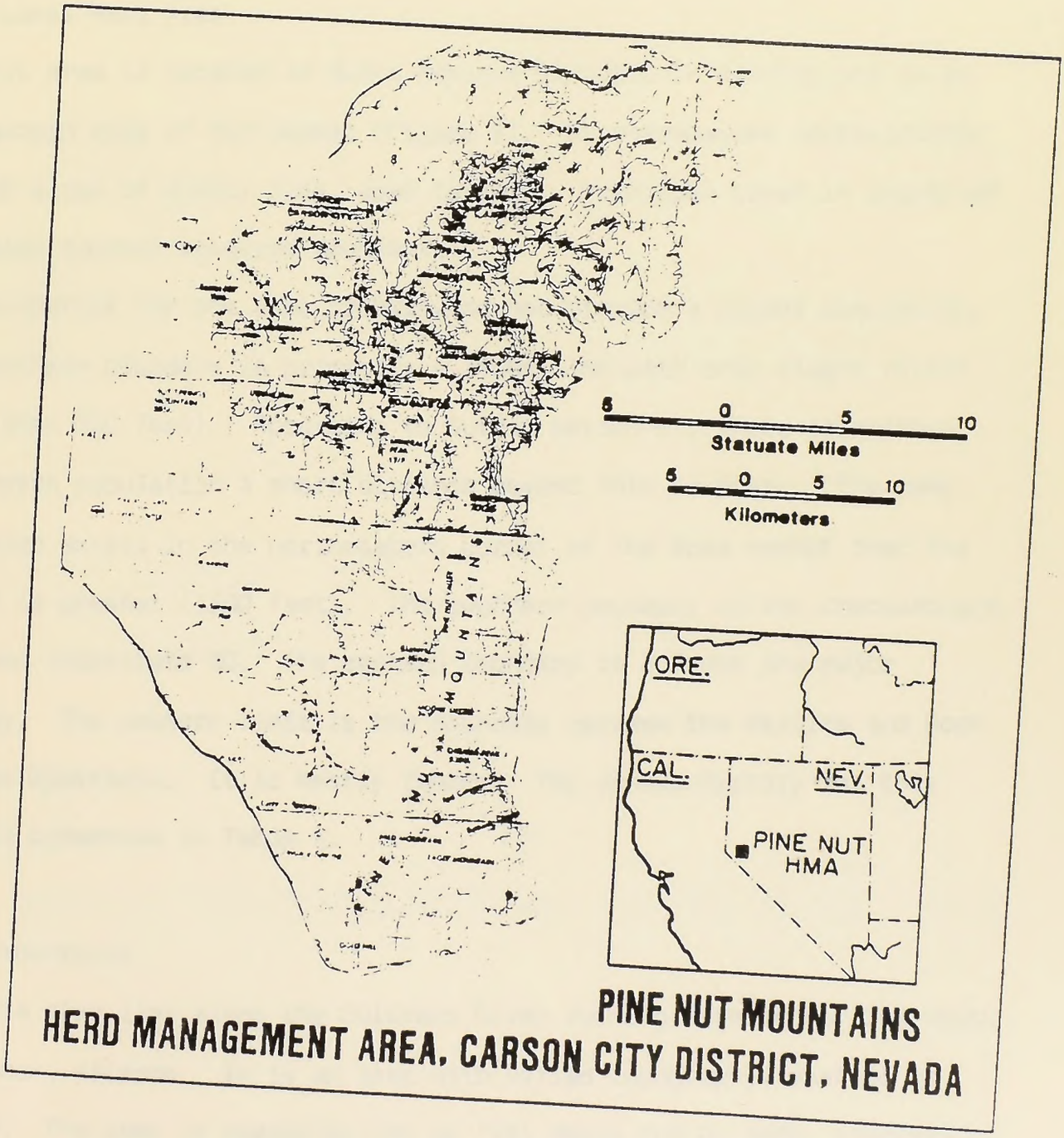


Figure 2. Location of Pine Nut Mountains, Herd Management Area, Nevada.



consists mainly of broad flat plateaus. Fences isolated the area from adjacent wild horse areas. The census history for this area is presented in Table 1.

Chain Lakes Herd Area

This area is located in BLM's Rawlins District in Wyoming and is on the eastern edge of Red Desert (Figure 4). It encompasses approximately 640,000 acres of mostly flat, open terrain. Principal cover is sagebrush and water sources appeared abundant.

Boundaries for the area probably do not provide a closed population. The northern boundary is primarily a ridge line with only slight relief (less than 500 feet). According to Bureau personnel, there is another wild horse population a short distance beyond this boundary. The same situation exists in the northeastern corner of the area except that the relief is greater (1500 feet). The southern boundary is the checkerboard area and Interstate 80. The eastern boundary is a fence and major highway. The western limit is the boundary between the Rawlins and Rock Springs Districts. It is mostly fenced. The census history for this area is presented in Table 1.

Black Mountains

This area lies along the Colorado River running from Hoover Dam south to Topock, Arizona. It is an area with varied topography, most of it rugged. The area is characterized by flat mesas cut by deep, steep-sided canyons. An alluvial fan drops gently off from the canyon area to the Colorado River.

Figure 3. Location of Beatys Butte Herd Management Area, Oregon.

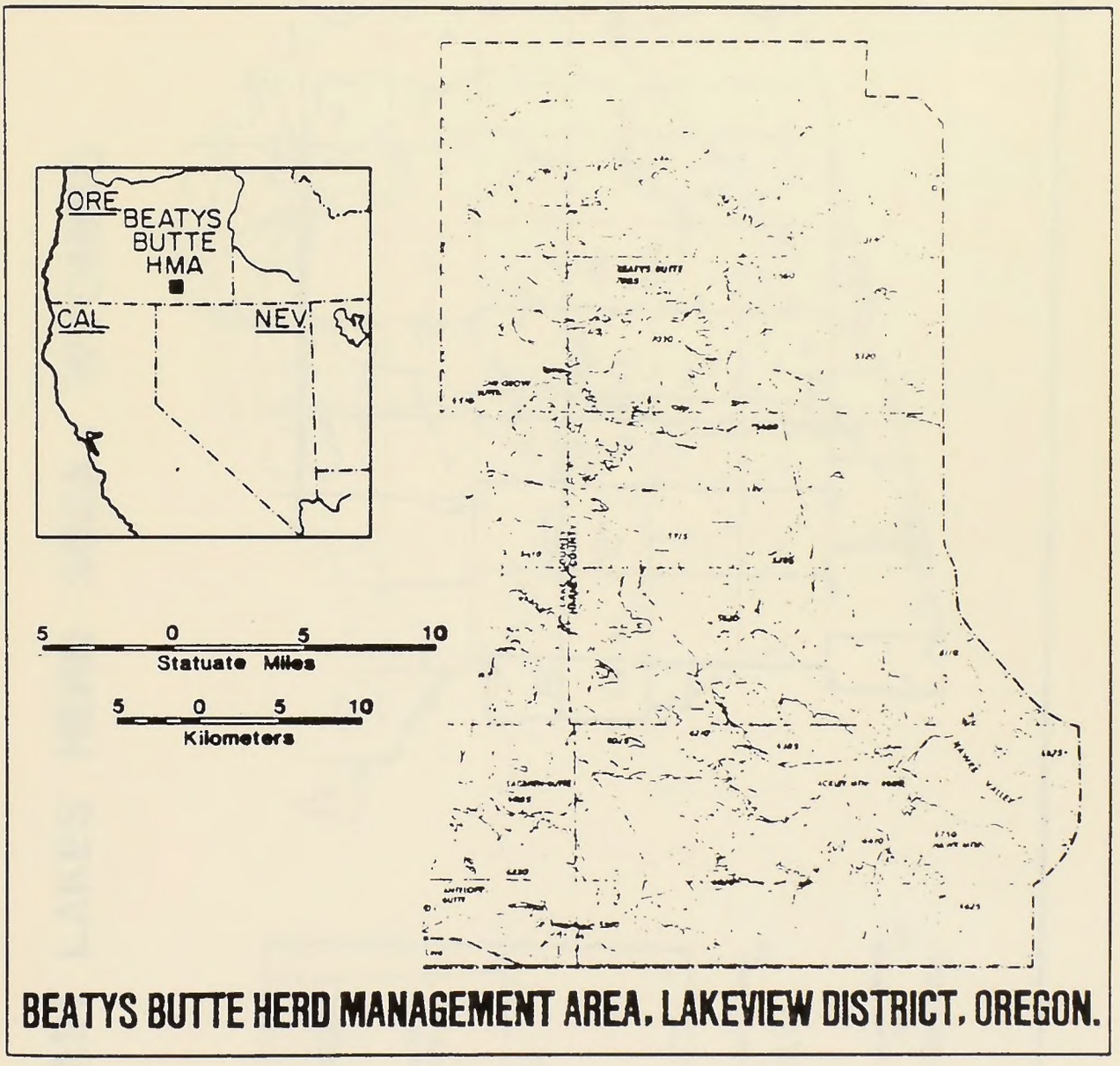


Figure 4. Location of Chain Lakes Herd Area, Wyoming.

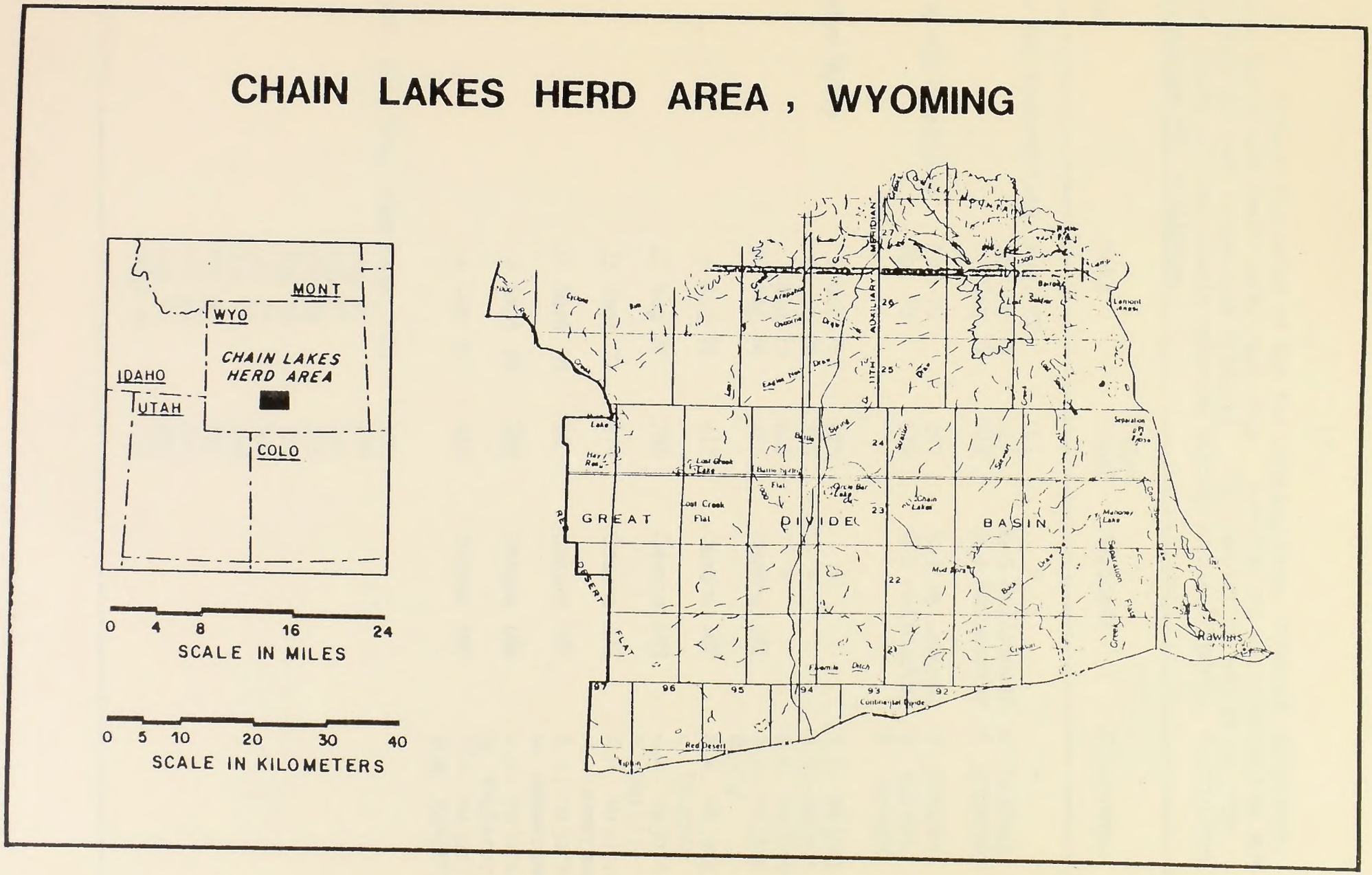


Table 1. Census histories of Pah Rah Mustang Area, Pine Nut Mountains, Beatys Butte and Chain Lakes Herd Area. Information was provided by BLM personnel in each respective District. All population estimates were total counts of individuals observed during census flights. * indicates information not available.

Area	Date	Total Count	Aircraft	Observers
Pah Rah Mustang Area	Aug. 72	101	*	*
	Spring 75	119	B-1 Helicopter	B. Stewart
	17 Dec 79	275	B-1 Helicopter	A. Anderson
Pine Nut Mountains	Feb 75	297	B-1 Helicopter	B. Stewart
	Apr 78	629	B-1 Helicopter	B. Nelson, B. Stewart
Beatys Butte	9 Oct 71	225	*	A.K. Majors
	7 Oct 72	323	*	A.K. Majors
	Aug 73	415	*	A.K. Majors
	17 Aug 74	476	Cessna 182	A.K. Majors Berry
	6 Aug 75	612	Cessna 182	A.K. Majors L. Doughty
	12 Aug 76	745	Cessna 182	A.K. Majors A. Gerity
	23 Sept 77	879	Cessna 172	A.K. Majors M. Hammersmark
	11 Sept 78	287	Cessna 182	A.K. Majors M. Hammersmark
	8 Sept 79	298	Cessna 180	A.K. Majors B. Whitaker
	14 Aug 80	419	Cessna 180	A.K. Majors D.B. Siniff
Chain Lakes Herd Area	Fall 1975	188		
	Aug 76	198		
	Aug 77	249		
	Oct 78	372		
	Dec 78	372		
	Mar 79	507		
	Oct 79	648		
	Mar 80	528		
	Nov 80	690		
	Mar 81	628		
	Sept 81	722		

Table 2. Flight information for census flights conducted on Pah Rah Mustang Area and Pine Nut Mountains HMA, Nevada during 1981, and Beatys Butte HMA, Oregon during 1980-81.

Area	Date	Hours of flight	Aircraft	Pilot	Observers	Flight time	Cloud cover	Snow cover
Pah Rah Mustang Area	17 Apr81	0630-1330	Piper Super Cub	Moore	McMahon	6.6	Broken	-
	21 Apr	0630-1300	Piper Super Cub	Moore	McMahon	6.0	Ceiling	-
	22 Apr	1000-1600	Piper Super Cub	Moore	McMahon	5.5	Clear	-
	29 Apr	0630-1330	Piper Super Cub	Moore	McMahon	6.9	Clear	-
	4 May	0630-1330	Piper Super Cub	Moore	McMahon	6.7	Clear	-
	5 May	0700-1330	B-2 Helicopter	Ron Crowe	McMahon-Sinliff	6.3	Broken	-
	3 Jul	0600-1100	B-2 Helicopter	Ron Crowe	McMahon-Clugston	4.3	Clear	-
	7 Jul	0600-1130	B-2 Helicopter	Ron Crowe	McMahon-Cook	4.4	Clear	-
	8 Jul	0600-1200	B-2 Helicopter	Ron Crowe	McMahon-Cook	5.7	Clear	-
	8 Jul	1300-1530	Cessna 180	Stewart	McMahon-Clugston	2.5	Clear	-
	7 Sep	0700-1400	B-2 Helicopter	Ron Crowe	McMahon-Clugston	6.7	Clear	-
Pine Nut Mountains	18-20 Feb	mornings	B-2 Helicopter	Archey	McMahon-Reuwsaat	13.5	Clear	-
	1-2 Jul	mornings	B-2 Helicopter	Ron Crowe	McMahon-Clugston	11.6	Clear	-
	9 Jul	0600-1200	Cessna 180	Stewart	McMahon-Clugston	5.5	Clear	-
	3-4 Sep	mornings	B-2 Helicopter	Ron Crowe	McMahon-Clugston	13.6	Clear	-
	17-18 Sep	mornings	Piper Super Cub	Moore	McMahon	9.0	Clear	-
Beatys Butte	14 Aug80	0640-1150	Cessna 180	Plato	Majors-Sinliff	5.2	Scattered	-
	14 Jan81	0800-1200	Cessna 180	Stewart	Majors-Whitaker	4.0	Clear	-
	24 Jan	1120-1500	Cessna 180	Plato	Whitaker-Ross	3.8	Broken	Scattered
	25 Jan	0830-1330	Cessna 180	Plato	Whitaker-McMahon	5.0	Scattered	Scattered
	1 Feb	1100-1600	Cessna 180	Plato	Whitaker-McMahon	5.0	Scattered	Mostly covered
	2 Feb	1230-1630	Cessna 180	Plato	Majors-Whitaker	4.0	Clear	Mostly covered
	3 Feb	1000-1510	Cessna 180	Plato	Whitaker-McMahon	5.2	Clear	Mostly covered
	4 Feb	0800-1245	Cessna 180	Stewart	Whitaker-McMahon	4.8	Clear	Mostly covered
	2 Mar	1000-1600	Cessna 180	Plato	Whitaker-McMahon	6.0	Scattered	N. slopes only
	3 Mar	0800-1300	Cessna 180	Plato	Whitaker-McMahon	5.0	Scattered	N. slopes only
	6 Mar	0820-1310	Cessna 180	Plato	Whitaker-McMahon	4.8	Scattered	Scattered
	12 Mar	0900-1230	Cessna 180	Plato	Whitaker-Joe K.	3.5	Clear	N. slopes only
	13 Mar	0845-1230	Cessna 180	Plato	Whitaker-McMahon	3.8	Scattered	N. slopes only
	14 Mar	0900-1125	Cessna 180	Stewart	Majors-McMahon	2.5	Clear	N. slopes only
	10 Apr	0815-1215	Cessna 180	Plato	Majors-Whitaker	4.0	Ceiling	-
	8 May	0700-1000	Cessna 180	Plato	Majors-Whitaker	4.0	Ceiling	Scattered

METHODS

Repetitive Censusing

Census flights were conducted on the Pah Rah Mustang Area and the Pine Nut Mountains from February through September 1981. A total of 173 radio and color collars had been placed on wild horses on these areas during fall 1980 and March 1981. Objectives of these flights were as follows:

1. Utilize sighting rate of collared animals to determine accuracy of total counts on these areas.
2. Obtain information on variability and precision of total counts by replication of census flights.
3. Evaluate relative utility of different aircraft in censusing. Three types of aircraft, a Piper Super Cub, Cessna 1[illegible] and a Bell 47G3B-2 helicopter, were utilized.

Each site was flown in a flight pattern to maximize coverage of the entire area; the majority of the flight time utilized is presented in Table 2. A cost analysis was made utilizing different types of aircraft.

The number on each collar was read during helicopter flights and provided an estimate of double counting. Double counting was estimated to be the percentage of collars that were noted more than once out of the total number of collars read during a census flight.

Repetitive census flights were made of Beatys Butte before and after a gathering of horses in February 1981. Information on these flights is also presented in Table 2. These flights were flown under a range of weather conditions and utilized observers with different levels of experience. The experienced observer was A. K. Majors (Lakeview District BLM) who had flown aerial censuses of the area yearly since 1971. The inexperienced observer was B. Whitaker (Lakeview District BLM) who had flown only one census previously.

The area was divided into 7 subunits and each subunit was censused separately. Horse locations and flight pattern were recorded on maps for each flight.

Calibration of an Index by Removal

A gathering of wild horses on Beatys Butte during February 1981 was used to evaluate a technique described by Seber (1973:376) and Eberhardt (1982) that uses removal data to calibrate indices. If indices to the number of horses on a given area before and after a removal are available (total counts can be used for the indices) the number removed can be used to calibrate the indices to obtain a population estimate. The estimate for the proportion counted is:

$$p=(X_1-X_2)/R$$

where

p = estimate of proportion counted

X_1 = count before removal

X_2 = count after removal

R = number removed

Replicate counts were conducted before and after removal of 272 horses during February 1981. A population estimate and an estimate of the proportion counted were then derived.

Mark-Resight Estimation

Numbered collars with and without radio transmitters were placed on horses on the Pah Rah and Pine Nut HMA areas during October and November 1980 (Table 3).

All collars were constructed of 4" wide 3 ply food conveyor belting. The white-colored belting was tapered to 1 1/2" wide in the area that fits under the neck to minimize wear and irritation to the horse that might develop from neck movement. All collars were numbered with 2" x 3" orange cattle tags for each digit. A 2" x 3" tag was also marked with a "T" for collars equiped with radio transmitters and left blank for collars that served as marker collars only. This was the only difference between marker and radio collars other than the radio.

Tag loss for collars was determined by relocating animals with radio collars. The effect of collaring on reaction to aircraft was evaluated by comparing the reaction of bands with collared animals to bands without collared animals.

Since we were always able to estimate the number of collars on an area they provided the basis for calculating a Lincoln-Peterson Index:

$$N = Mn/m$$

where

N = estimated number of animals

M = number of available collars on an area

n = number of animals resighted (both collared and uncollared)

m = number of collars resighted

One Piper Supercub, 1 Cessna 180 and 3 B-2 helicopter flights of the Pine Nuts were conducted during 1981. Total count estimates as well as Lincoln-Peterson estimates were obtained for all flights except the Cessna 180 flight. It was not possible to obtain accurate collar counts during this flight.

Five Piper Supercub, 5 B-2 helicopter flights and 1 Cessna 180 flight were conducted on the Pah Rah area durng 1981. Total counts as well as Lincoln-Peterson estimates were obtained. During all flights on the Pah Rah and Pine Nut areas, counts of adults only were used as foaling was occurring during this time period.

Two experiments were designed to evaluate the effectiveness of paint marking for providing a mark-resight estimation of population size. The first evaluation was done on the Pah Rah Mustang Area on 7-8 July 1981 using a B-2 helicopter. Orange paint pellets and a CO_2 marking pistol

Table 3. Wild horses collared on Pah Rah Mustang Area and Pine Nut Mountains, Carson City district, Nevada.

Area	Collar Type		
	Radio	Color	Total
Pah Rah Mustang Area	37	39	76
Pine Nuts - North end	49	39	88
Pine Nuts - South end	9	0	9
Totals	95	78	173

manufactured by the Nelson Paint Company (Iron Mountain, Michigan) were used to mark 102 horses on 7 July. The area was flown in the same flight pattern used for total counts. Once a group had been spotted, a number of animals were marked based on the size of the group. In groups of 1-5 animals, 1 horse was marked; 6-10, 2 horses were marked; 11-15, 3 were marked and so on. No concious selection process was used for deciding which members of the group to mark. Collared animals that were marked were noted.

A resight flight was conducted on 8 July 81 also using a B-2 helicopter. This flight was again flown in the typical flight pattern for total counts. Once a group was located, it was checked for paint marks and any collared animals with marks were noted.

Group Size Visibility Bias

Visibility bias of different group sizes was evaluated using the 2 observer design of Cook and Jacobson (1979). In this model, the observability of a particular band size is determined as follows:

where $$\alpha_s = 1 - \frac{X_{2s}}{X_{1s}}$$

αs = probability of observing a band of size s by an observer

X_{1s} = number of bands of size s seen by the primary observer

X_{2s} = number of bands of size s seen by the secondary observer that were missed by the primary observer.

Two observers are required for this model; therefore, a Cessna 180 was utilized. Both observers sit on the same side of the airplane. The person in front serves as the primary observer while the person in back serves as the secondary observer. The primary observer serves as the primary locator, noting all bands he sees. The secondary observer only notes bands the primary observer fails to see. Once a band is spotted both observers aid in determining how many horses are in the band. The pilot and any other observers in the plane were instructed to inform the primary and secondary observers of the presence of a band only after the plane had well passed the band and the primary and secondary observer had failed to note it. In this manner, visibility bias information was collected while keeping the flights as similar to routine BLM census flights as possible.

This technique was utilized on a number of census flights on Beatys Butte. It was also utilized to evaluate censusing on the Chain Lakes Herd Area in Wyoming. Two flights were conducted on this area during November 1981.

Variables Affecting Accuracy

Snow and cloud conditions were noted on all flights. An estimate of the percent of the area covered with snow was made as well as the snow background for each band sighting. Background categories were no cover, scattered, and complete cover. Cloud condition was obtained from Federal Aviation Administration Flight Service Station reports. These conditions are broken into 4 categories: clear, scattered, broken and ceiling with

an altitude given for each cloud layer. The effects of cloud and snow cover on total counts as well as on visibility bias of group sizes were examined.

Observer fatigue was evaluated using the Cook-Jacobson group size visibility bias model. Census flights were divided into a first half and second half and the probability of an observer sighting a group of a particular size in the first half of the flight was compared to the probability of observing that same group size in the second half.

The effect of observer experience was evaluated during the Beatys Butte census fligh̄s. Replicate flights were flown by an experienced BLM observer who had participated in censuses of the area yearly since 1971 and by inexperienced observers who either had flown the area only once or not at all. Observer experience was also evaluated during flights on the Chain Lakes Herd Area using the Cook-Jacobson model.

Double counting was evaluated during helicopter flights on the Pah Rah and Pine Nut Areas. During these flights, all collar numbers were noted. Double counting was estimated to be the percentage of collars that were noted more than once out of the total number of collars observed.

On every census flight, we recorded whether horse groups were moving or standing still when first spotted. This allowed an evaluation of the importance of movement to the observability of different size groups. This was further examined in relation to aircraft type and census history. It had been suggested that horses would become adjusted to aircraft because of the repeated census flights and their reaction

would be reduced over time. The response of collared versus non-collared animals was also evaluated.

Relationship of Band Sizes to Population Density

Band sizes were recorded on all flights. Mean band sizes were compared for flights prior to and following the gathering. Also examined were records for census flights conducted on Beatys Butte between 1971 and 1980. The relationship of mean band size to population density as indicated by fall total count data was examined.

Strip-Transect Estimation

An initial evaluation of strip transects was made to determine the sampling intensity needed to provide reliable population estimates. Computer simulation of strip-transect sampling of a population distribution of 623 horses on the Pah Rah Mustang Area was conducted at various levels of sampling intensity. Horse locations and numbers were those from the 5 May 1981 helicopter census of the Pah Rahs. Sampling intensity was based on the percentage of the area covered using randomly selected 1/2 mile wide strips. Observability was assumed to be 100% for the evaluation. One thousand simulations were made, and coefficients of variation were calculated for flights at each level of sampling intensity.

Quadrat Sampling

An initial evalution of quadrat sampling was made using computer simulation. Horse distribution information collected during a census

flight of the Pine Nut Mountains provided the population. Various levels of sampling intensity for randomly selected 1 mile square plots were examined to determine the sample intensity needed to provide reliable population estimates. One thousand simulations were run at 28 levels of sampling intensity ranging from 2% to 92% of the area covered. No stratification was attempted.

Burro Census

A typical BLM burro census was observed during late May 1981 in the Black Mountains, Phoenix District, Arizona. Burros on a portion of this area had been censused during a previous research project by Walker and Ohmart (1978). Paint marking was utilized to provide a Lincoln-Peterson estimate of the population size and sighting rates were compared between the two censuses. Also evaluated was the new paint delivery system being developed by the 3M Company of St. Paul, Minnesota.

Foaling

Observations of collared females were made during helicopter censuses to determine whether or not they had foals. These observations were made on the Pah Rah Mustang Area during census flights on 5 May, 3 July and 7 September 1981. On the Pine Nut Mountains, observations were made on 7 May, 2 July, 21 July and 4 September 1981.

An additional 70 females were equipped with radio collars during December 1981 and February 1982. Observation of foaling by these females as well as females collared earlier in the study is now underway.

Chemical Immobilization

In order to attach the radio collars to females, it was decided to use chemical immobilization as the method of capture. This allowed us to selectively place collars in various bands.

The primary drug selected for immobilization was etorphine hydrochloride (M-99). Evaluations of drug doses were conducted at Palamino Valley Corrals. Based on these trials, a combination of 5.5 mg etorphine, 150 mg Xylazine (Rompum) and 3 mg atropine was selected for field use. One of the primary advantages of using M-99 is the availability of an antidote, diprenophine hydrochloride (M 50/50).

A Palmer Cap-Chur gun with a 7 ml dart was used with green charges to deliver the drug from a B-1, B-2 or Salony helicopter. We attempted to select females on the basis of apparent pregnancy or presence of a foal. Once an animal was darted and down, a radio collar was attached, the animal was aged and/or photographs taken of the teeth, blood samples were drawn on most animals for pregnancy tests, measurements of vital signs were taken, and the antidote was administered.

RESULTS

Accuracy of Total Counts

Total counts obtained before and after the gathering on Beatys Butte are listed in Table 4. Counts before the gathering, including both experienced and inexperienced observers, had a mean of 397 with a 95% confidence interval of ± 23 horses (6%). Counts following the gathering had a mean of 145 horses with a 95% confidence interval of ± 7 horses (5%).

Table 5 utilizes the various combinations of minimum and maximum counts obtained before and after the gathering to derive the range of population estimates possible using the calibration of an index by removal method. Means of counts before and after gathering indicated that, on the average, 93% of the horses on the area were being counted.

Total counts obtained on census flights of Pah Rah Mustang Area are shown in Table 6. Lincoln-Peterson estimates using the number of collared animals on the area as the marked population are also given. As indicated the proportion of collared animals observed on each replicate count remained fairly constant for both fixed wing and helicopter. Clearly there was more variation for the helicopter counts; however, these counts were carried out over a much longer time frame. Also shown is the mean and standard error for the replicate counts. As indicted, the average number seen for Super Cub flights is slightly below that seen during helicopter censuses while the standard error is somewhat lower. This small difference in results obtained by use of different aircraft is

Table 4. Total count results for flights on Beatys Butte HMA, Oregon, before and after a gathering of 272 horses in February 1981.

BEFORE		AFTER	
DATE	COUNT	DATE	COUNT
14 Aug 80	419	2 Mar 81	141
14 Jan 81	437	3 Mar 81	153
24 Jan 81	408	6 Mar 81	136
25 Jan 81	350	12 Mar 81	146
1 Feb 81	374	13 Mar 81	132
2 Feb 81	384	14 Mar 81	150
3 Feb 81	407	10 Apr 81	150
4 Feb 81	393	8 May 81	153
$\bar{x} = 397$		$\bar{x} = 145$	
$ts_{\bar{x}} = \pm 23$		$ts_{\bar{x}} = \pm 7$	

Table 5. Population estimates using the calibration of an index by removal method for combinations of minimum and maximum counts obtained before and after removal, Beatys Butte, HMA, Oregon.

RANGE OF COUNTS

BEFORE	AFTER
437 - 350	153 - 132

REMOVAL METHOD

BEFORE		AFTER	ESTIMATE
437	-	132	390
350	-	132	436
437	-	153	418
350	-	153	483

$\bar{x} = 432$

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Table 6. Total count and Lincoln-Peterson estimates for flights conducted on Pah Rah Mustang Area, Nevada. Counts and estimates are for adult animals only.

Date	Total Count	Collars Available	Collars Observed	Lincoln-Peterson Estimate
PIPER SUPER CUB				
17 Apr 81	353	74	41	637
21 Apr 81	353	74	39	670
22 Apr 81	480	74	43	826
29 Apr 81	432	74	41	780
4 May 81	442	74	40	818
$\bar{x}$	412.0	-	-	746.2
$s_{\bar{x}}$	25.4	-	-	39.0
B2 HELICOPTER				
5 May 81	518	74	50	768
3 July 81	454	70	43	739
7 July 81	388	70	33	821
8 July 81	577	70	62	651
7 Sept 81	422	70	44	671
$\bar{x}$	471.8	-	-	730.0
$s_{\bar{x}}$	33.9	-	-	31.2
CESSNA 180				
8 July 81	422	70	32	923

not statistically significant. The census using the Cessna 180 on 8 July gives an unusually high estimate for the Lincoln-Peterson, which is due to the very small fraction of collars observed. Reasons for this discrepancy will be be considered in the discussion portion of the paper.

Figure 5 presents 95% confidence intervals (using a Poisson model) for each of the Lincoln-Peterson estimates. As can be seen in this figure, only 1 total count was within the confidence interval for the Lincoln-Peterson estimate for the same flight.

The paint marking experiment on the Pah Rahs on 7-8 July 81 resulted in a Lincoln-Peterson estimate of 709 animals. An estimate based on collars for the same 8 July flight was 651 animals. A total of 102 animals were paint marked and 83 were resighted.

Figure 6 presents locations of individuals observed on 3 different flights, each using a different aircraft type. The wild horse population was concentrated into 2 areas and the two flights on the same day indicate differences due to aircraft type and prior disturbance. Also, differences among the counts relate to the variations in counts on concentration areas.

The helicopter counts for the Pah Rah Mustang Area were used as a basis for Jolly-Seber estimates. These data are shown in Table 7 and form the basis for 3 estimates of the population size for 3, 7, and 8 July. Comparing these with the previous Lincoln-Peterson estimates it is seen that they are more variable with an average population estimate below the average for the Lincoln-Peterson. Since this method is an open population model it, in theory, allows estimates of movement into and out

Figure 5. Lincoln-Peterson estimates and their 95% confidence intervals for census flights on Pah Rah Mustang Area, Nevada. Circles indicate the total count obtained on each flight.

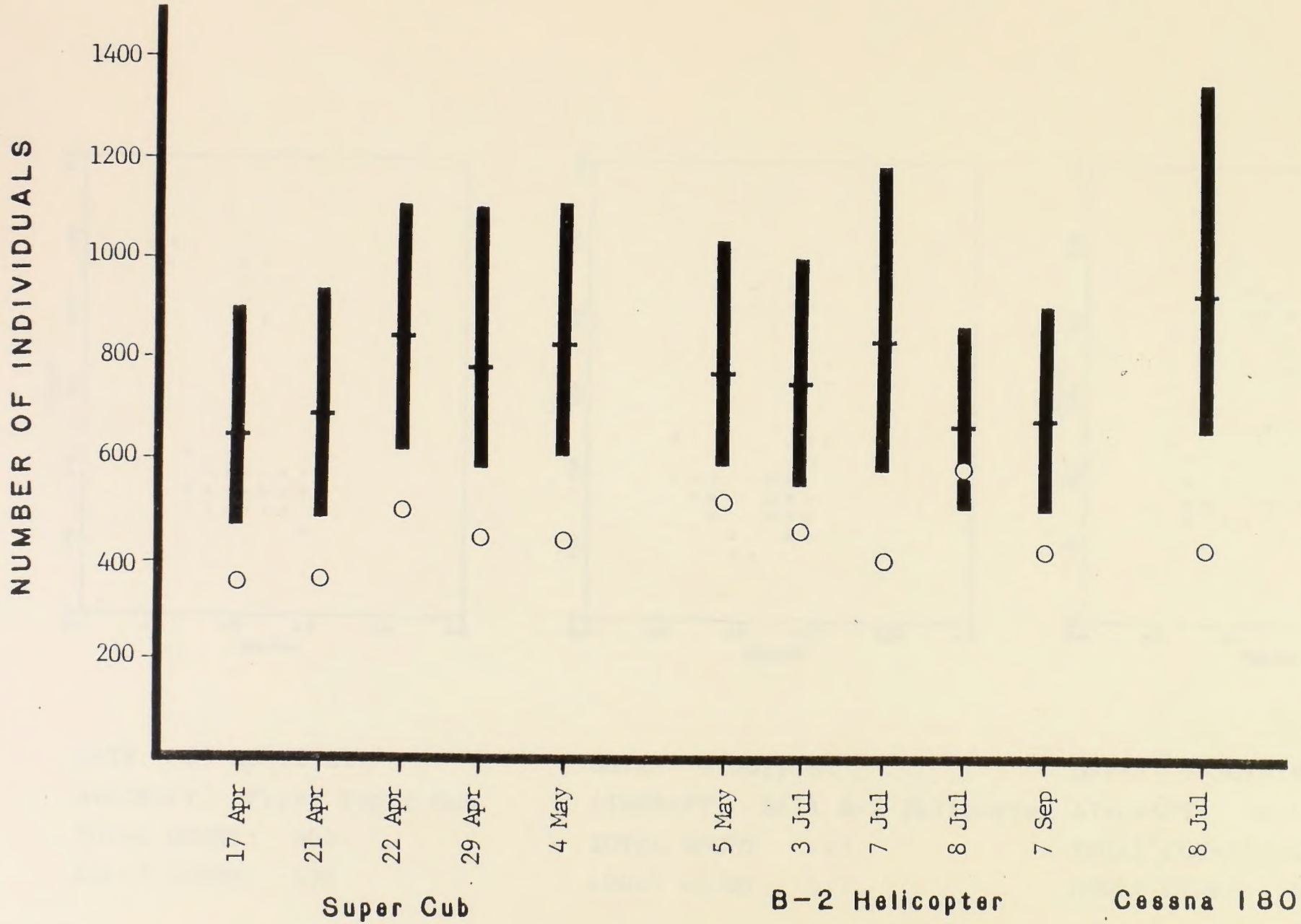
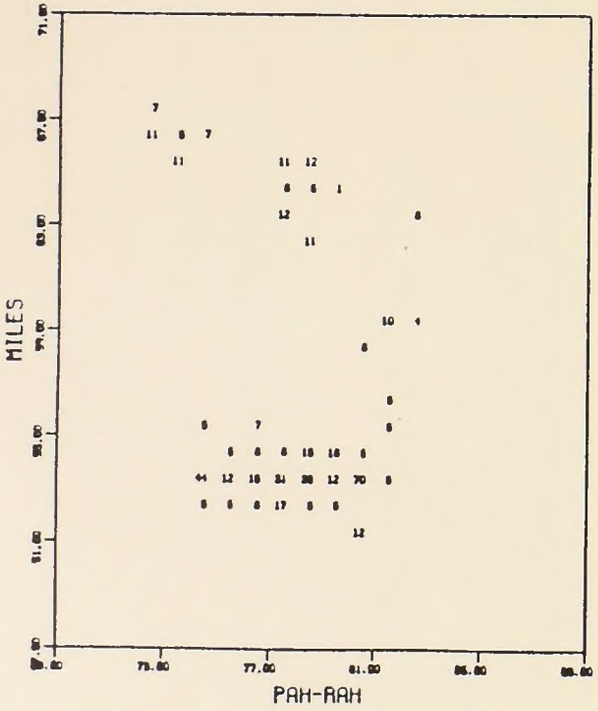
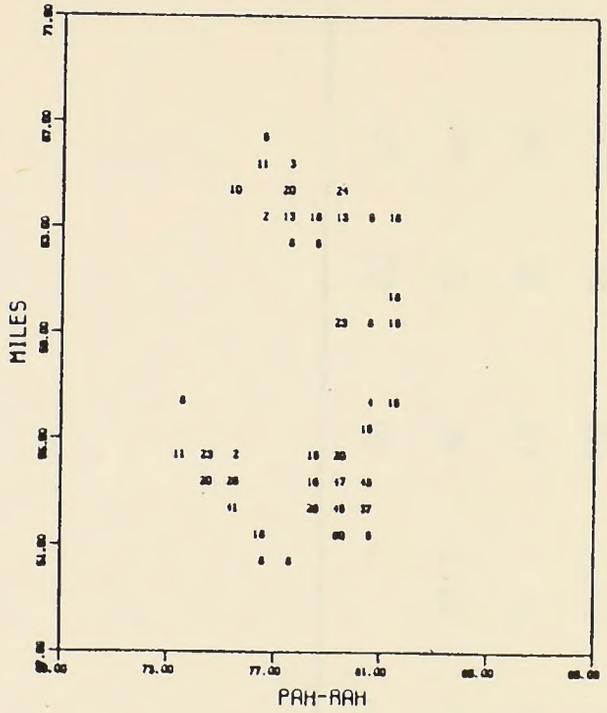


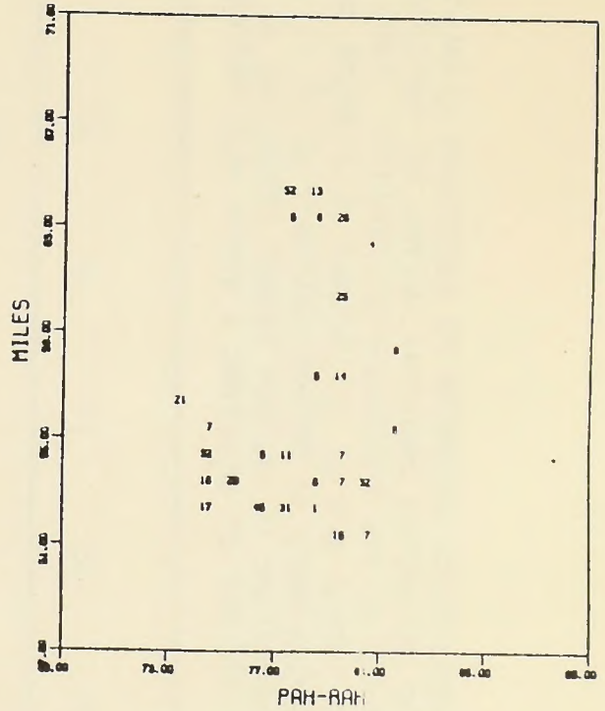
Figure 6. Locations of individuals sighted during 3 censuses of Pah Rah Mustang Area, Nevada using a Piper Super Cub, Bell B-2 Helicopter, and a Cessna 180.



DATE: 29 April 81
AIRCRAFT: Piper Super Cub
TOTAL COUNT: 502
ADULT COUNT: 432



DATE: 8 July 81
AIRCRAFT: Bell B-2 Helicopter
TOTAL COUNT: 718
ADULT COUNT: 577



DATE: 8 July 81
AIRCRAFT: Cessna 180
TOTAL COUNT: 468
ADULT COUNT: 422

Table 7. Seber-Jolly estimates of selected adult population parameters based on collar resightings for aerial censuses conducted on Pah Rah Mustang Area, Nevada, during 1981. Estimating equations are as given by Seber (1973); n_i is the number of animals in sample, m_i is the number of marked animals observed on day i, f_i is fraction marked in population, p_i is probability of capture, M_i is estimated number marked in population, N_i is the estimated population size where i pertains to the ith census.

Census date	i	n_i	m_i	f_i	p_i	M_i	N_i	SE_{N_i}
5 May	1	518	-	-	-	-	-	-
3 July	2	454	35	.08	.77	46.6	588.7	46.3
7 July	3	388	26	.07	.52	51.3	739.1	99.2
8 July	4	577	53	.09	1.02	53.0	567.3	11.9
7 Sept	5	422	38	.09	-	-	-	-

of the population. However this movement is considered to be permanent once accomplished (Seber 1973). One gets the impression that immigration and emmigration may have been considerable between census periods. However, this is probably an artifact since it seems unlikely in the short time frame for these census operations. It would appear that even though the Jolly-Seber Method allows some relaxation of assumptions it is not as precise as the Lincoln-Peterson estimate for these populations, and further work is needed on its statistical characteristics in dealing with clumped marking patterns.

Total counts of the Pine Nut Mountain study area have been more infrequent because its size and complexity increase the cost considerably. Table 8 presents data from the censuses where complete counts of the entire area were undertaken. Since the number of replicates involved in all the cases is relatively low we did not calculate other statistics. The proportion of collared animals found remains very consistent from one census period to the next. It seems likely that in this area the total count is more affected by physical conditions during the census operation. The reasons for the consistency of the proportion of marked animals found also may be related to the problem of random allocation of collars among the population as a whole, causing the probability of sighting to vary among individuals because of the group size bias.

Figure 7 presents 95% confidence intervals (using a Poisson model) for each Lincoln-Peterson estimate. None of the total counts obtained were within these intervals.

Table 8. Total count and Lincoln-Peterson estimates for flights conducted on Pine Nut Mountains, Nevada. Counts and estimates are for adult animals only.

Date	Total Count	Collars Available	Collars Observed	Lincoln-Peterson Estimate
PIPER SUPER CUB				
17-18 Sept 81	295	89	32	820
B2 HELICOPTER				
18-20 Feb 81	344	64	28	786
1-2 July 81	367	92	47	718
3-4 Sept 81	297	89	46	575
CESSNA 180				
9 July 81	193	-	-	-

Figure 7. Lincoln-Peterson estimates and their 95% confidence intervals for census flights on Pine Nut Mountains, Nevada. Circles indicate the total count obtained on each flight.

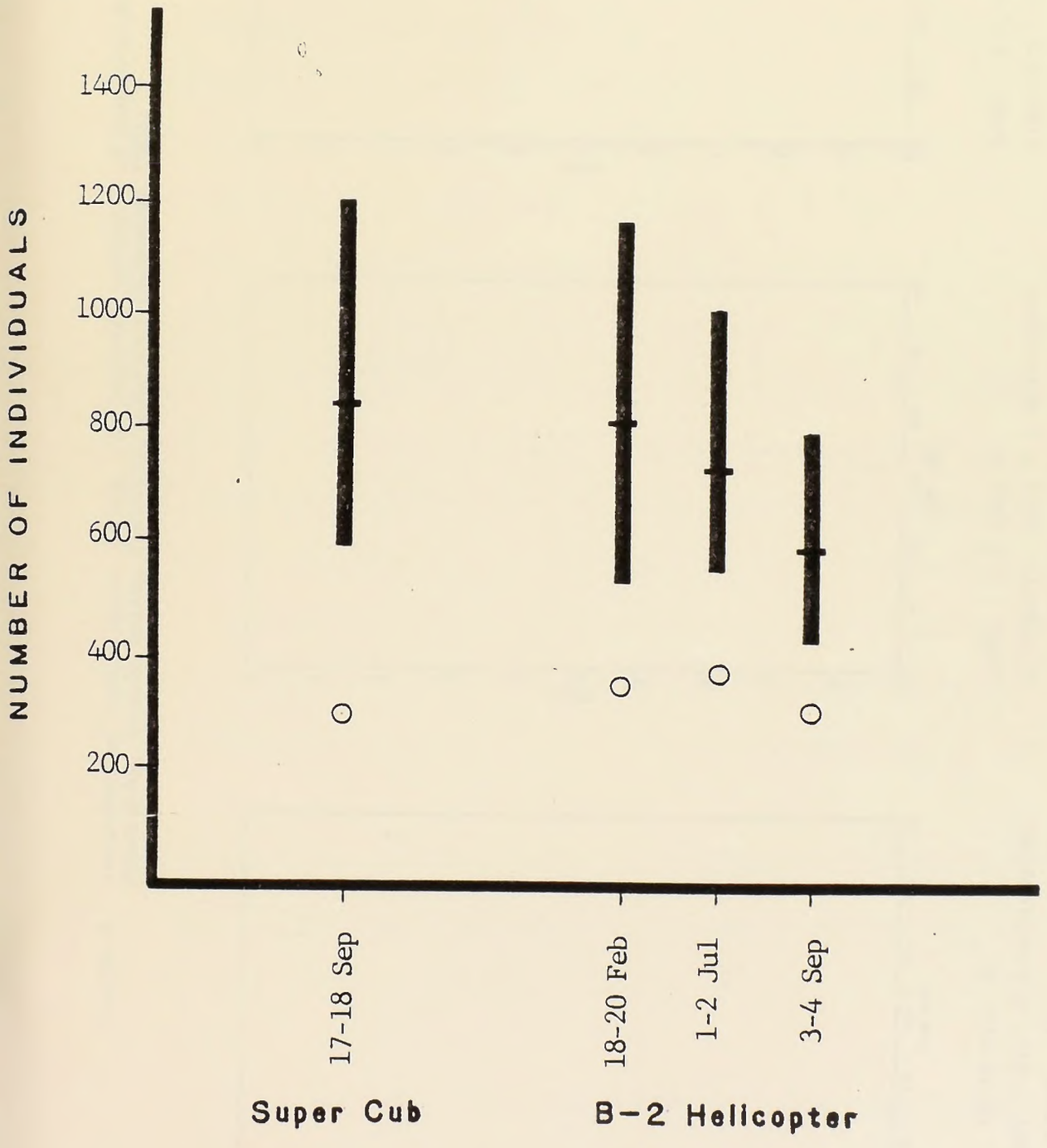
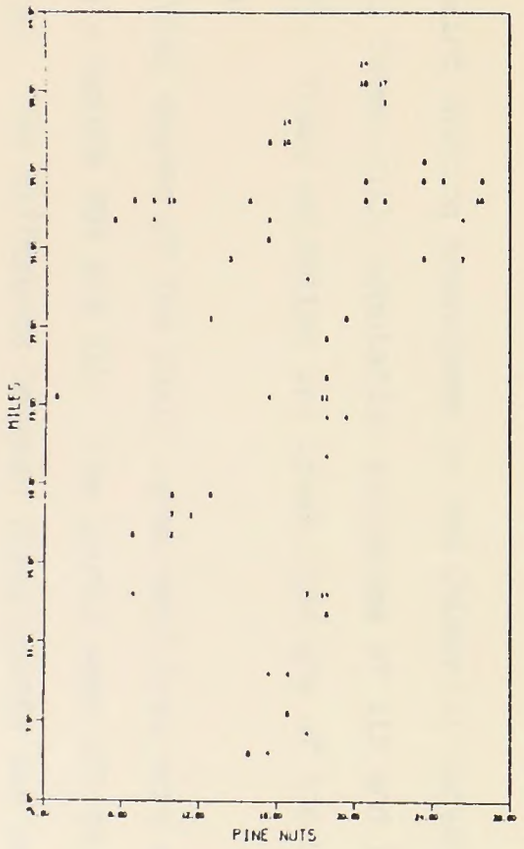
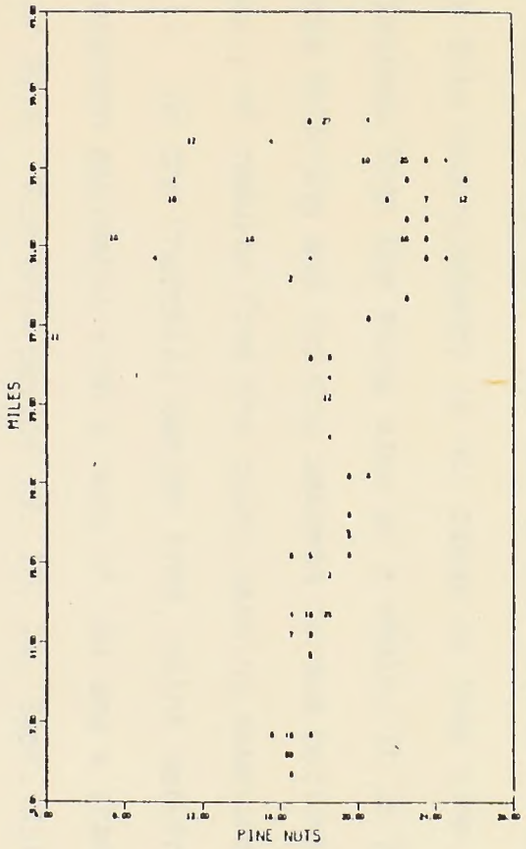


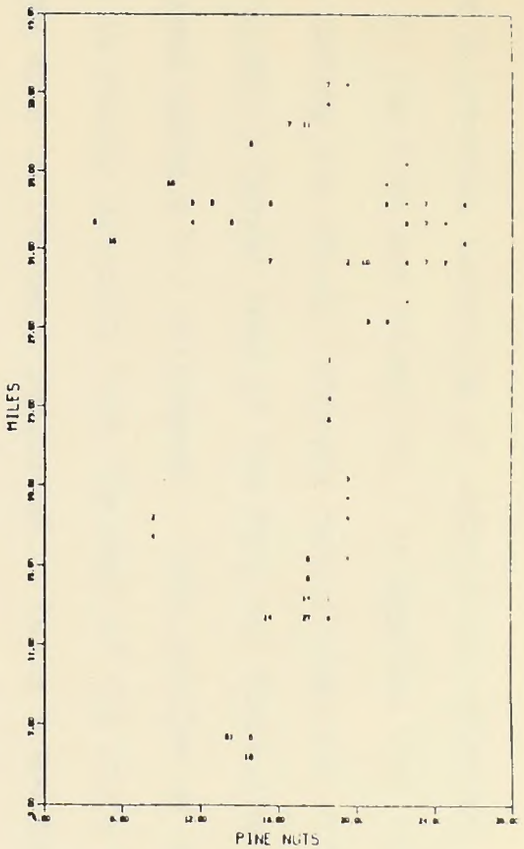
Figure 8. Locations of individuals during 3 helicopter censuses of the Pine Nut Mountains, Nevada during February, July and September 1981.



DATE: 18-20 Feb. 81
AIRCRAFT: Bell B-2 Helicopter
TOTAL COUNT: 344
ADULT COUNT: 344



DATE: 1-2 July 81
AIRCRAFT: Bell B-2 Helicopter
TOTAL COUNT: 433
ADULT COUNT: 367



DATE: 3-4 Sept. 81
AIRCRAFT: Bell B-2 Helicopter
TOTAL COUNT: 356
ADULT COUNT: 297

Figure 8 presents locations of individuals observed during helicopter censusing of the Pine Nut Mountains. It appears that horses were more dispersed during the 18--20 February census than the other 2 censuses.

The Churchill Canyon Area of the Pine Nut Mountains was censused several times using a B-2 helicopter. This portion of the Pine Nut Mountains is fairly discrete from the rest of the study area. Replicate counts were made on the days indicated in Table 9 and these formed the basis for Jolly-Seber estimates (Table 10). As indicated, these estimates vary considerably from one census period to the next. The reason for this inconsistency is not clear at this time. Since this area is less discrete than the study area as a whole, it is possible that animals were entering and leaving between census periods.

A summary of results from the paint marking experiment are presented in Table 11. On the Churchill Canyon Area, paint marking provided 6 Lincoln-Peterson estimates with a mean of 184 and a standard deviation of the mean of 21.9. For this period (9, 10, 11, Sept. 81) collars provided 3 estimates with a mean of 158 and a standard deviation of the mean of 8.3.

The paint marking experiment on the Churchill Canyon Area also provided 2 Seber-Jolly population estimates of 115 and 136 individuals (Table 10). These estimates are lower than any of the Lincoln-Peterson estimates.

Two total counts of the Chain Lakes Herd Area were completed utilizing a Cessna 206 and 210. The counts were 875 on 6 Nov 81 and 886 on 7 Nov 81. The difference between these counts was only 1.3%.

Table 9. Total count and Lincoln-Peterson estimates for flights conducted on the Churchill Canyon area of Pine Nut Mountains, Nevada. Counts and estimates are for adult animals only.

Date	Total count	Collars Available	Collars Observed	Lincoln-Peterson estimate
B-2 HELICOPTER				
7 May 81	138	58	42	191
2 July 81	115	58	38	176
21 July 81	112	58	32	203
3 Sept 81	82	56	40	115
8 Sept 81	72	56	16	252
9 Sept 81	87	56	32	152
10 Sept 81	63	56	24	147
11 Sept 81	87	56	28	174
$\bar{x}$	94.5	-	-	176.2
$S\bar{x}$	8.8	-	-	14.6

Table 10. Seber-Jolly estimates of selected adult population parameters based on collar and paint mark resightings for aerial censuses conducted on Churchill Canyon area of Pine Nut Mountains during 1981. Estimating equations are as given by Seber (1973); n_i is the number of animals in sample, m_i is the number of marked animals observed on day i f_i is fraction marked in population, p_i is probability of capture, M_i is estimated number marked in population, N_i is estimated population size, where i pertains to the ith census.

Census date	i	n_i	m_i	f_i	p_i	M_i	N_i	SE_{Ni}
Collars								
7 May	1	138	-	-	-	-	-	-
1 July	2	115	24	.22	.65	38.3	177.7	19.8
21 July	3	112	27	.25	.55	50.6	204.3	28.6
3 Sept	4	82	30	.37	.81	37.7	100.9	6.7
8 Sept	5	72	16	.23	.43	39.4	169.1	28.3
9 Sept	6	87	29	.34	.73	40.4	118.6	10.8
10 Sept	7	63	22	.36	.54	41.9	116.7	18.0
11 Sept	8	87	28	.33	-	-	-	-
Paint Marks								
8 Sept	1	72	-	-	-	-	-	-
9 Sept	2	87	15	.18	.76	20.9	114.9	15.9
10 Sept	3	63	14	.23	.46	32.0	136.5	33.3
11 Sept	4	87	19	.23	-	-	-	-

[1] M_i is the number of marked animals observed on day i.

ble 11. Summary of paint marking experiments on Churchill Canyon Area of the Pine Nut ntains, Nevada during 1981. Estimates are for adult animals only.

Area	Marking date	Color	Number Marks	Number Collars	Resight date	n	Marks Resight	Marks Pop. Est.	Collars Resight	Collars Pop. Est.
Churchill Canyon	8 Sept	Orange	25	56	9 Sept	87	15	145	32	152
					10 Sept	63	6	262	24	147
					11 Sept	87	9	242	28	174
	9 Sept	Green	28	56	10 Sept	63	13	136	24	147
					11 Sept	87	15	162	28	174
	10 Sept	Yellow	20	56	11 Sept	87	11	158	28	174

Variables Affecting Accuracy

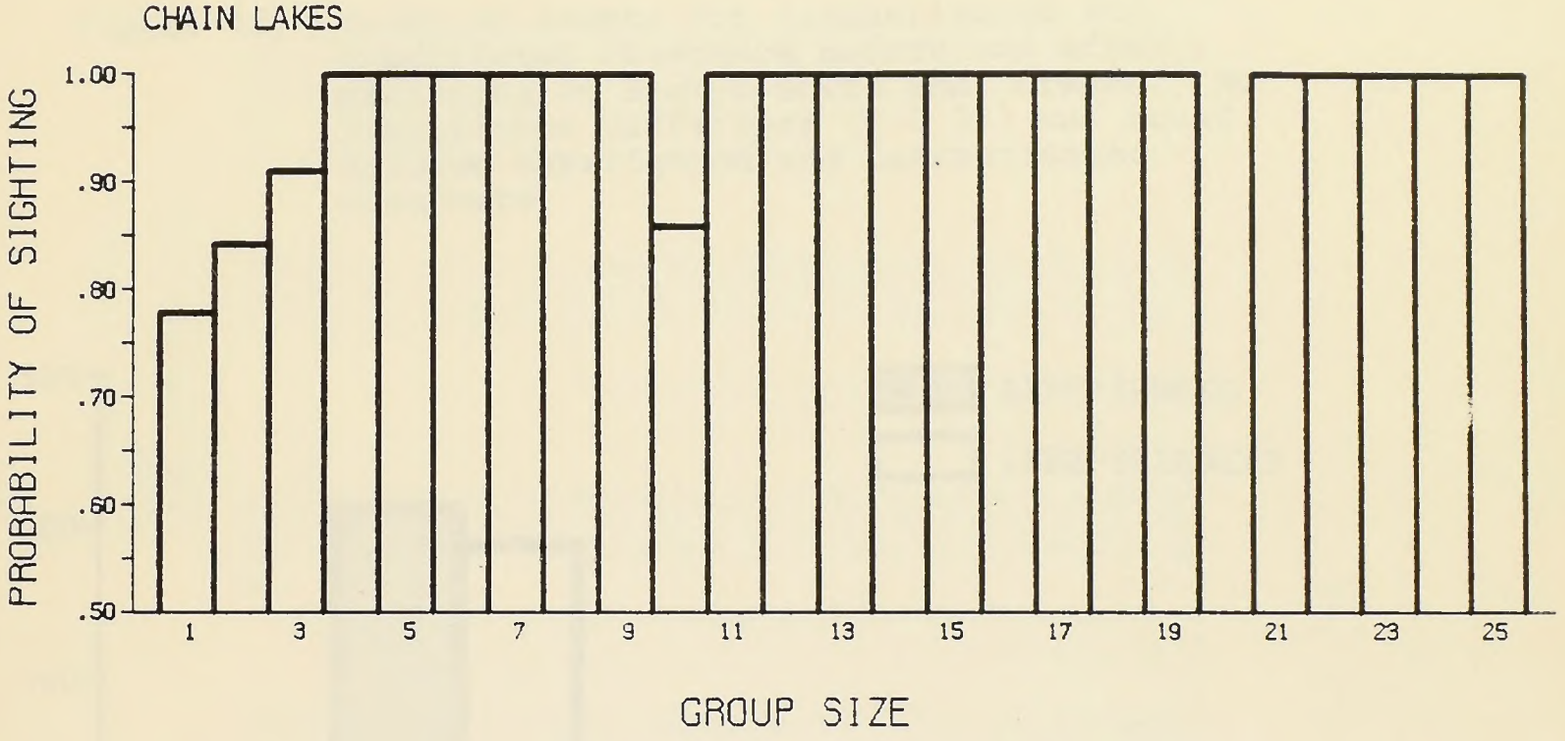
The probabilities of observation of different size groups by a single observer are presented in Figure 9 for flights on Beatys Butte and on Chain Lakes. On Beatys Bute, the trend was for smaller groups, in particular groups of less than 5 horses, to be less observable than larger groups. On Chain Lakes, results indicate that there is very little problem in sighting groups of any size on this area. There was only a slight visibility bias in detecting groups of size 1-3.

The difference in sighting rates between the two areas was largely due to presence of a snow cover which reduced observability on some of the flights on Beatys Butte. It should also be emphasized that these are sighting rates for one observer, most routine BLM census flights use more than one observer.

Observer experience did not appear to be a significant factor affecting accuracy of the total counts on Beatys Butte. There was not a significant difference ($p > 0.05$) between the counts by experienced and inexperienced observers either before or after the gathering (Figure 10).

Observer experience as a factor affecting census counts was further examined during the census flights on the Chain Lakes Herd Area. The ability of an observer who had never flown an aerial horse census to detect various size groups was compared to that of an experienced observer (approximately 300 hours flight time). The results of this analysis are presented in Figure 11. There was little difference in the ability of the 2 observers to detect different size groups.

Figure 9. Group size visibility bias results for groups observed during flights on Beatys Butte, Oregon and Chain Lakes Herd Area, Wyoming during 1981. Results for Beatys Butte are from 9 flights which included 373 observations. Results from Chain Lakes are from 2 flights and include 215 observations.



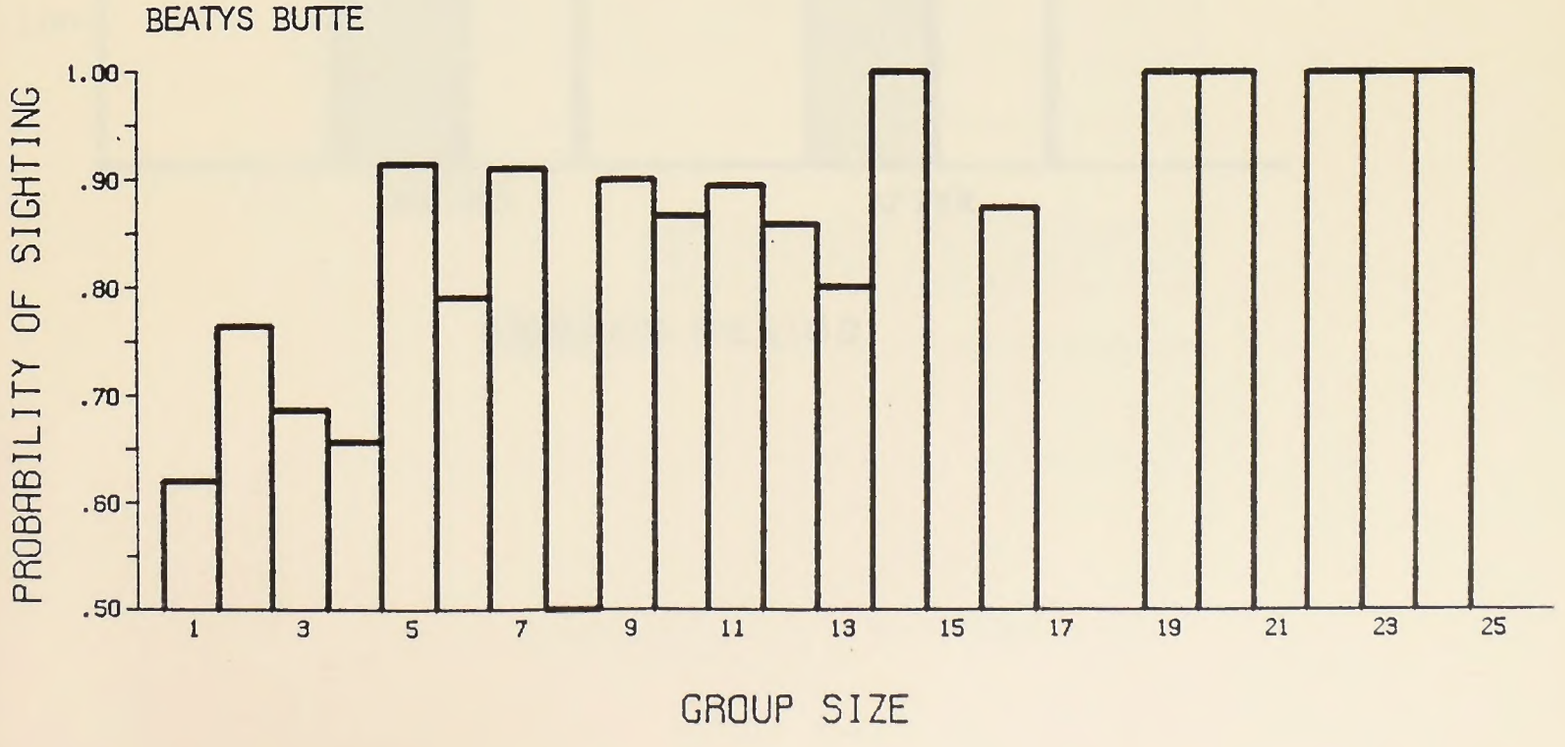


Figure 10. Means of counts for inexperienced and experienced observers before and after a gathering on Beatys Butte HMA, Oregon. No significant difference ($p>0.05$) was found between experienced and inexperienced observers.

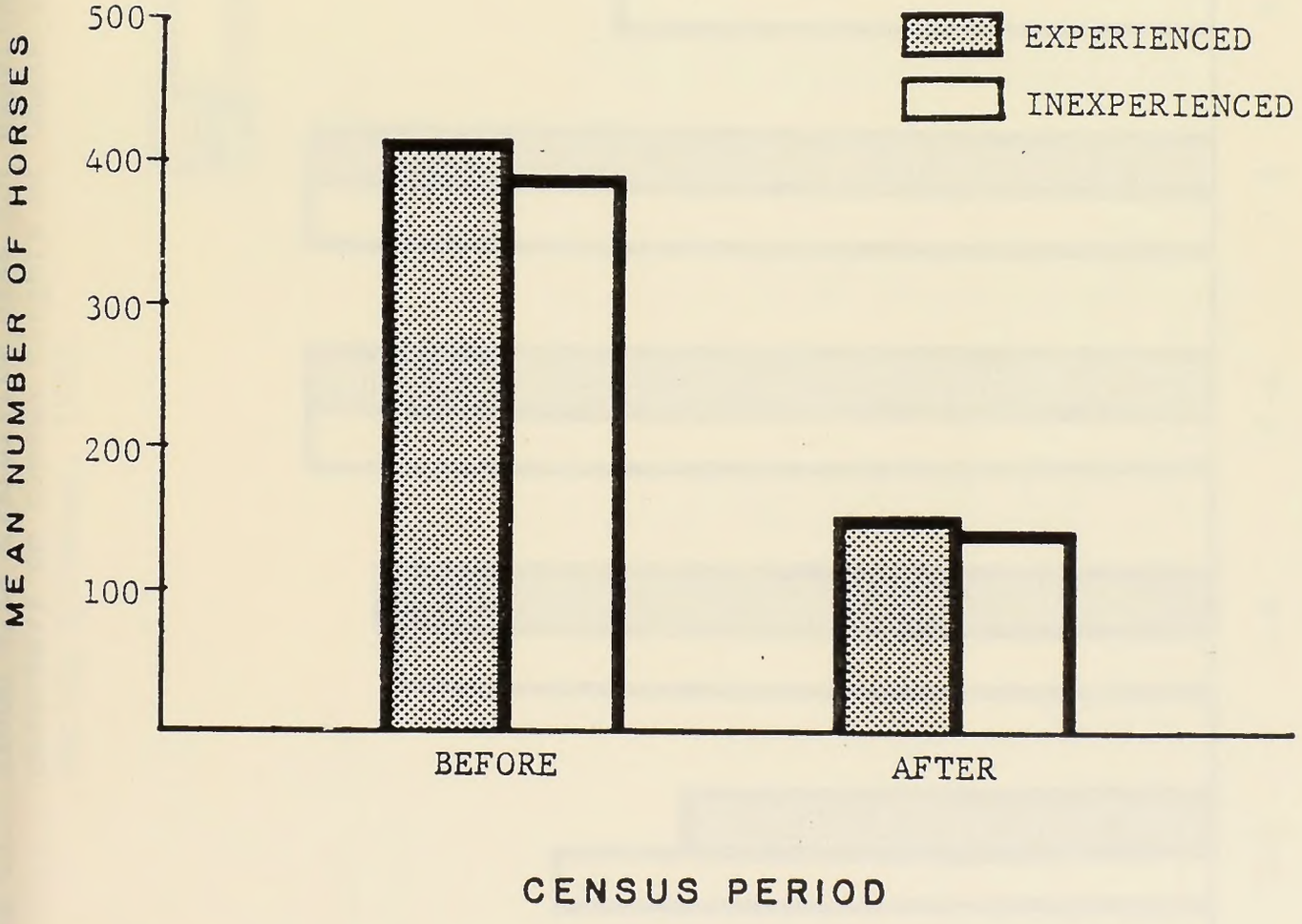


Figure 11. Group size visibility bias for experienced versus inexperienced observers on census flights of Chain Lakes Herd Area, Wyoming during November, 1981.

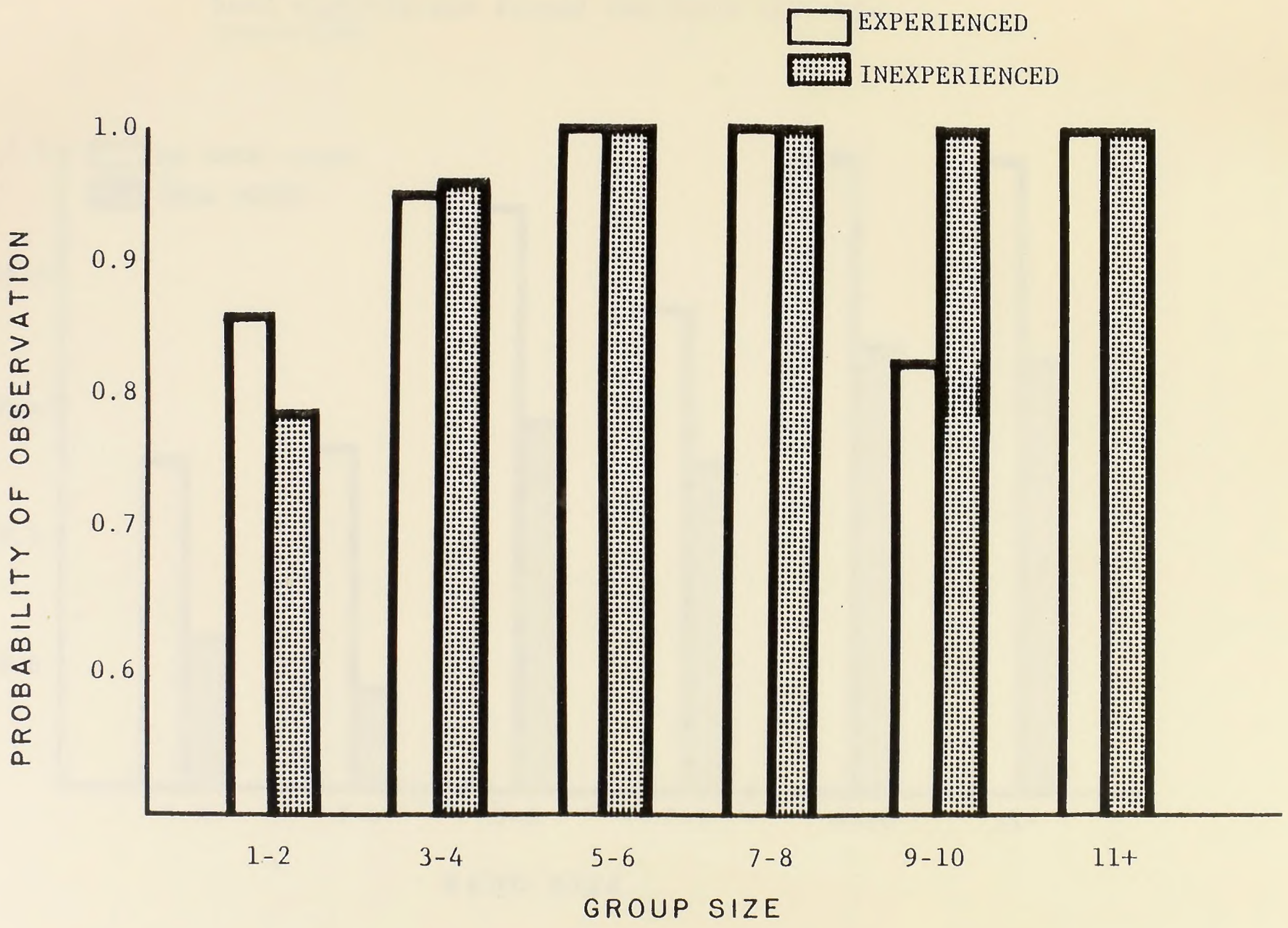
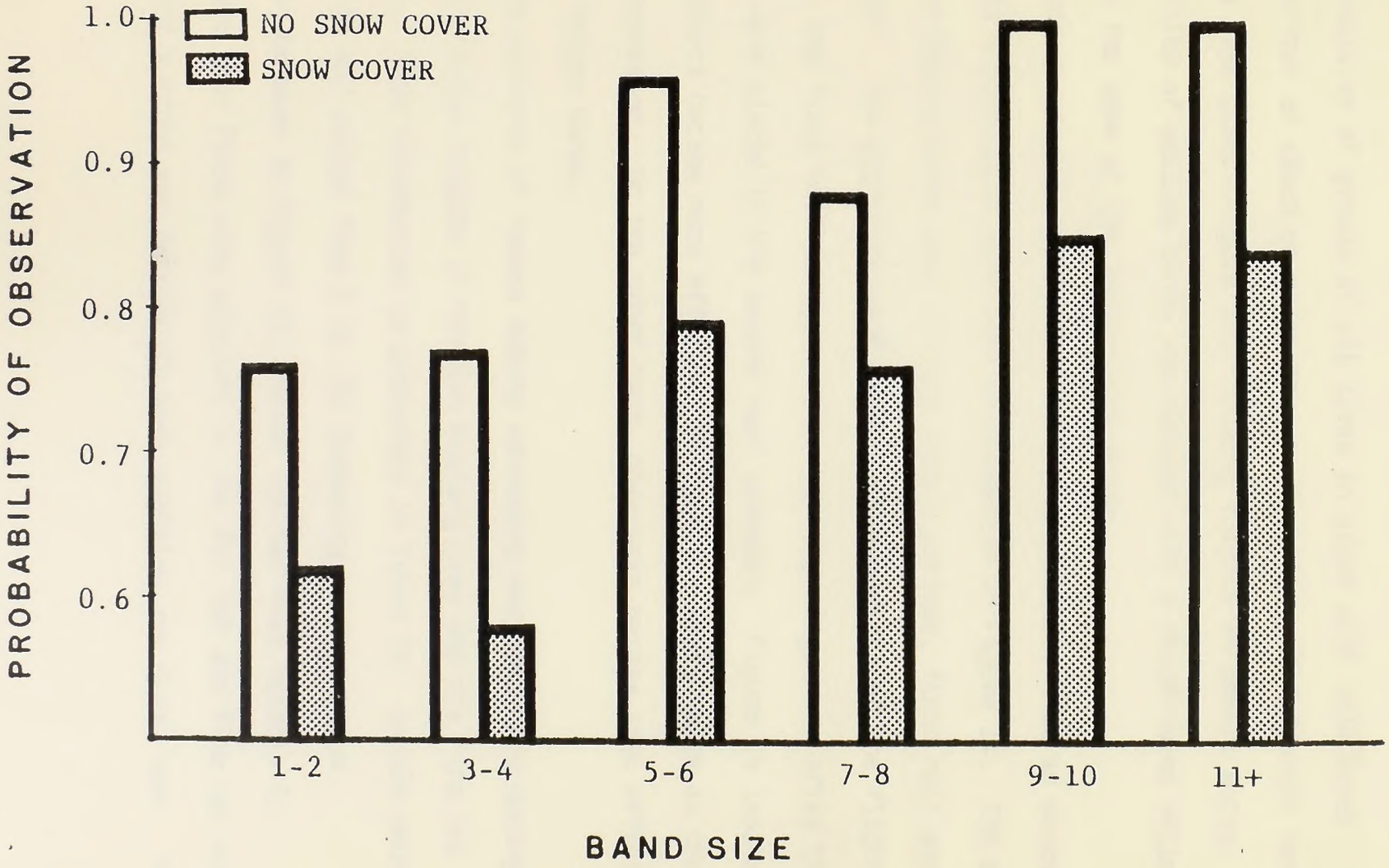


Figure 12. Effect of snow cover on group size visibility bias, Beatys Butte, HMA, Oregon. Absence or presence of a snow background was noted for each band sighting and formed the basis for this comparison.



Snow cover proved to have a significant negative effect on the number of horses counted. This was best demonstrated by sighting rates for groups in areas with snow cover compared to areas without snow during flighs on Beatys Butte. Figure 12 shows that there was a sharp reduction in observability of groups of all sizes in areas with snow cover.

The effect of cloud cover on the observability of different band sizes was less clear (Figure 13). During flights on Beatys Butte, observability of smaller bands was reduced with a cloud cover while it increased for some of the larger band sizes.

The effect of observer fatigue on the probability that an observer will sight a particular size band is presented in Figure 14. The census flights on Beatys Butte were divided into 2 periods, first half and second half. All sightings made before the midpoints of the flights were placed in the first half category while all sightings made after the midpoint were placed in the second half category. Figure 14 indicates that observers became more efficient at spotting small bands as the flight progressed. On the other hand, observers became less efficient at spotting larger bands.

Double counting of horses during censusing was evaluated during helicopter census flights of Pah Rah Mustang Area and the Pine Nut Mountains. This information is presented in Table 12. Double counting averaged 5% and ranged from 0 to 15% depending on the census.

As can be seen in Figure 15, horses reacted more readily to helicopters than fixed wing aircraft on the Pah Rah and Pine Nut areas. Movement of a group was determined when sighting was first made. Results

Figure 13. Effect of cloud cover on group size visibility bias, Beatys Butte HMA, Oregon.

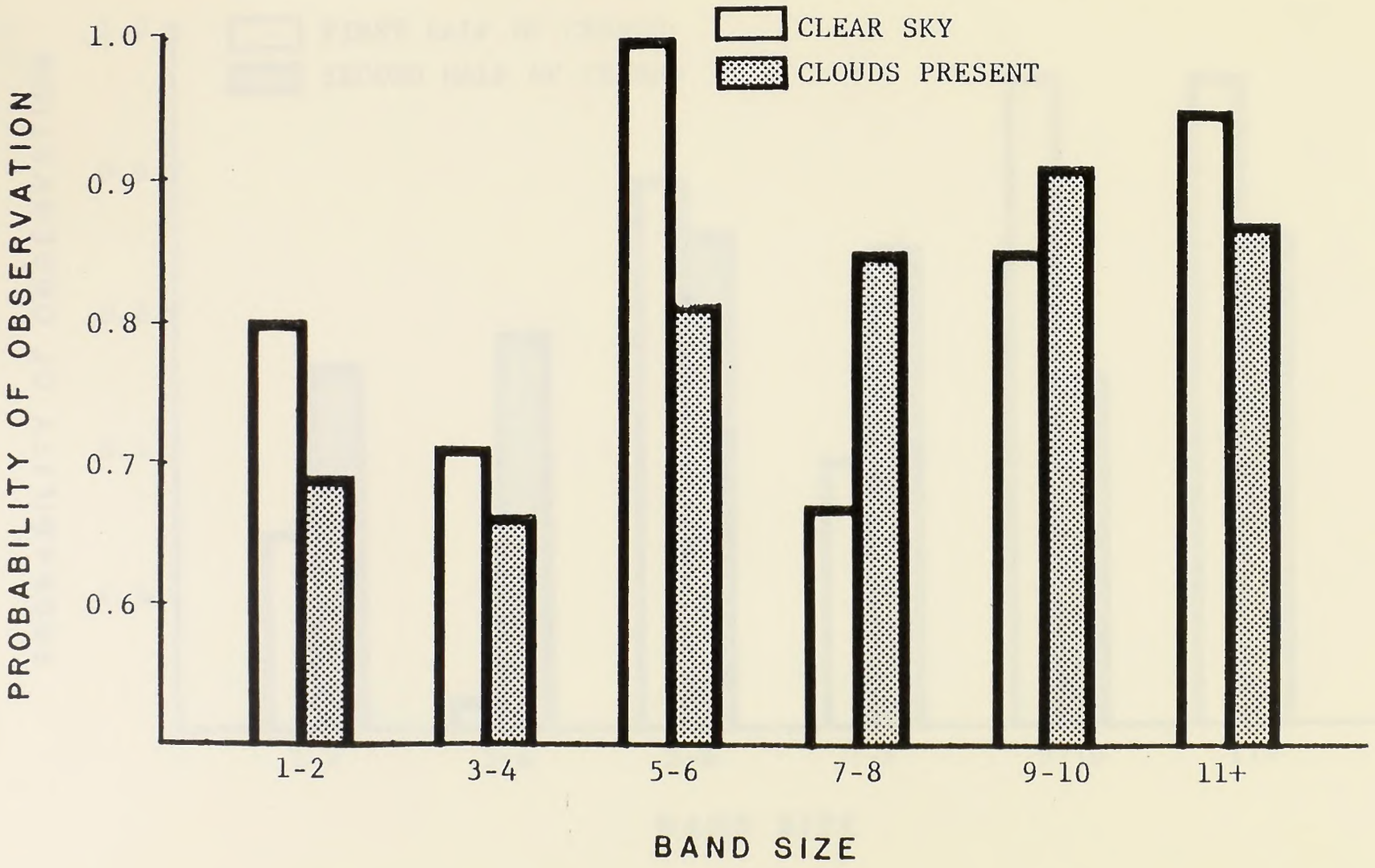


Figure 14. Effect of observer fatigue on group size visibility bias, Beatys Butte HMA, Oregon. Censuses were divided into observations made before the midpoint of the flight and those made after the midpoint.

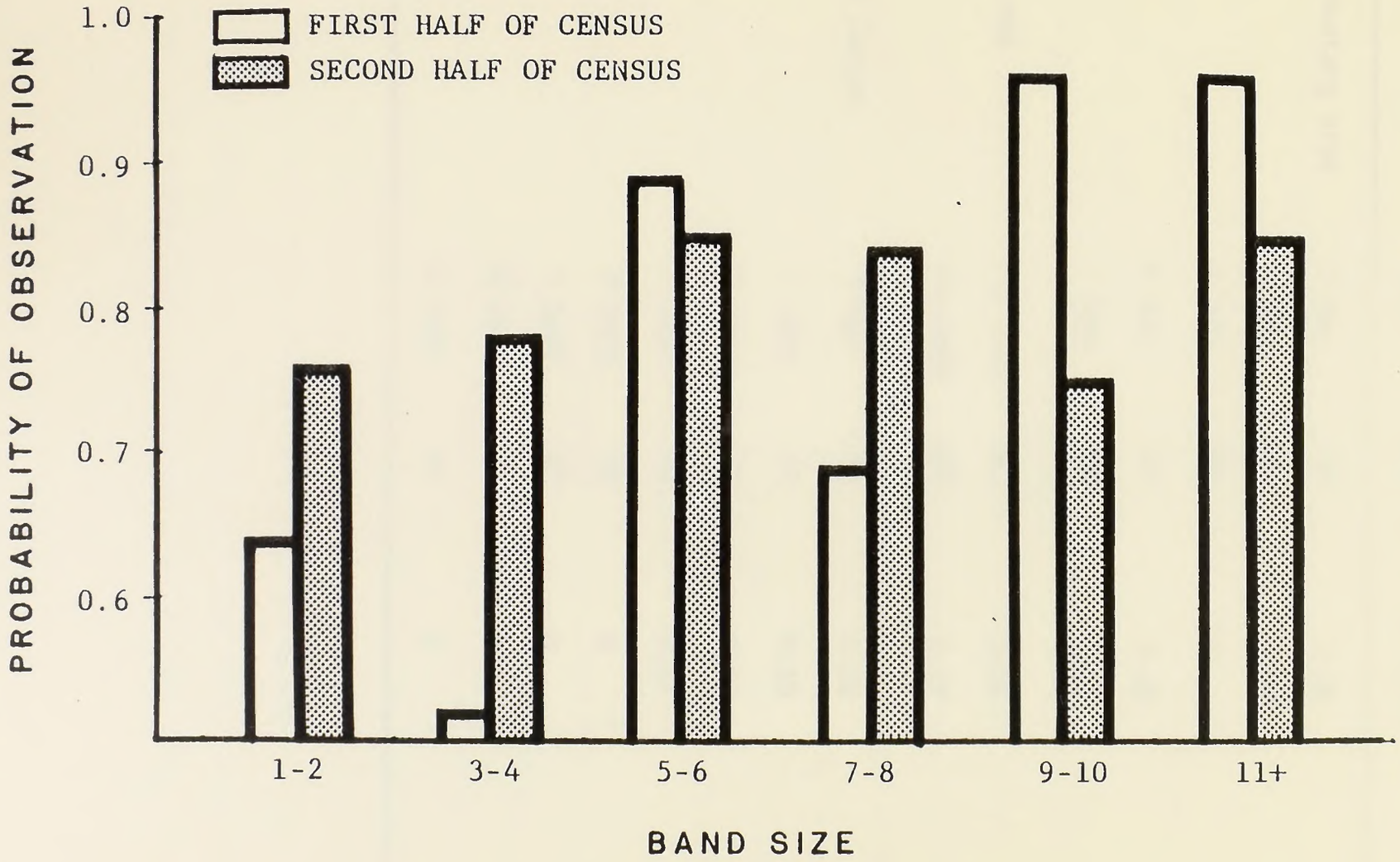


Table 12. Estimates of double counting as determined from collared horses during census flights in Nevada during 1981. Double counting averaged 5% over these 15 censuses.

Area	Date	Total count	Double count estimate	Corrected total count
Pah Rah Mustang Area	5 May	518	0.08	477
	3 July	454	0.02	445
	7 July	388	0	388
	8 July	577	0.10	519
	7 Sept	422	0.11	376
Pine Nut HMA	1-2 July	367	0.06	344
	3-4 Sept	297	0.13	258
Churchill Canyon	7 May	138	0.02	135
	2 July	115	0.10	104
	21 July	112	0.03	108
	3 Sept	82	0.15	70
	8 Sept	72	0	72
	9 Sept	87	0	87
	10 Sept	63	0	63
	11 Sept	87	0	87

also suggest that groups of less than 4 horses were less likely to react to aircraft than larger groups. These data would also indicate that double counting maybe more of a problem with helicopters since more reation and mixing of bands seems indicated.

The influence of movement in sighting groups of various sizes was evaluated using data collected at Beatys Butte. As can be seen in Figure 16, there is not a clear trend for movement influencing sighting rates. It appeared to reduce observability of smaller groups but increased the observability of larger groups.

This analysis is important in evaluating the effects of collaring on the behavior of horses during census flights. Groups with collared horses reacted more readily to both fixed wing aircraft and helicopters than groups not containing collared horses (Figure 15). This movement would mean that smaller groups with collared animals would be observed less often than expected while the opposite would be true for larger groups. It is unclear how these results may effect the Lincoln-Peterson estimates.

In mark-recapture studies an important assumption is that all individuals, whether marked or not, have an equal chance of being captured (observed) during census operations. This is tantamount to assuming that the population is sampled at random during the marking process so that all individuals, regardless of age, sex, physiological condition, have an equal chance of falling into the marked sample. As we have shown in previous analyses, the group size with which horses are associated may have a bearing on the probability of detection. The

Figure 15. Reaction of horses to aircraft for bands on the Pah Rah Mustang Area and Pine Nut Mountains, Nevada. Bands were classified as either moving or not moving when first spotte

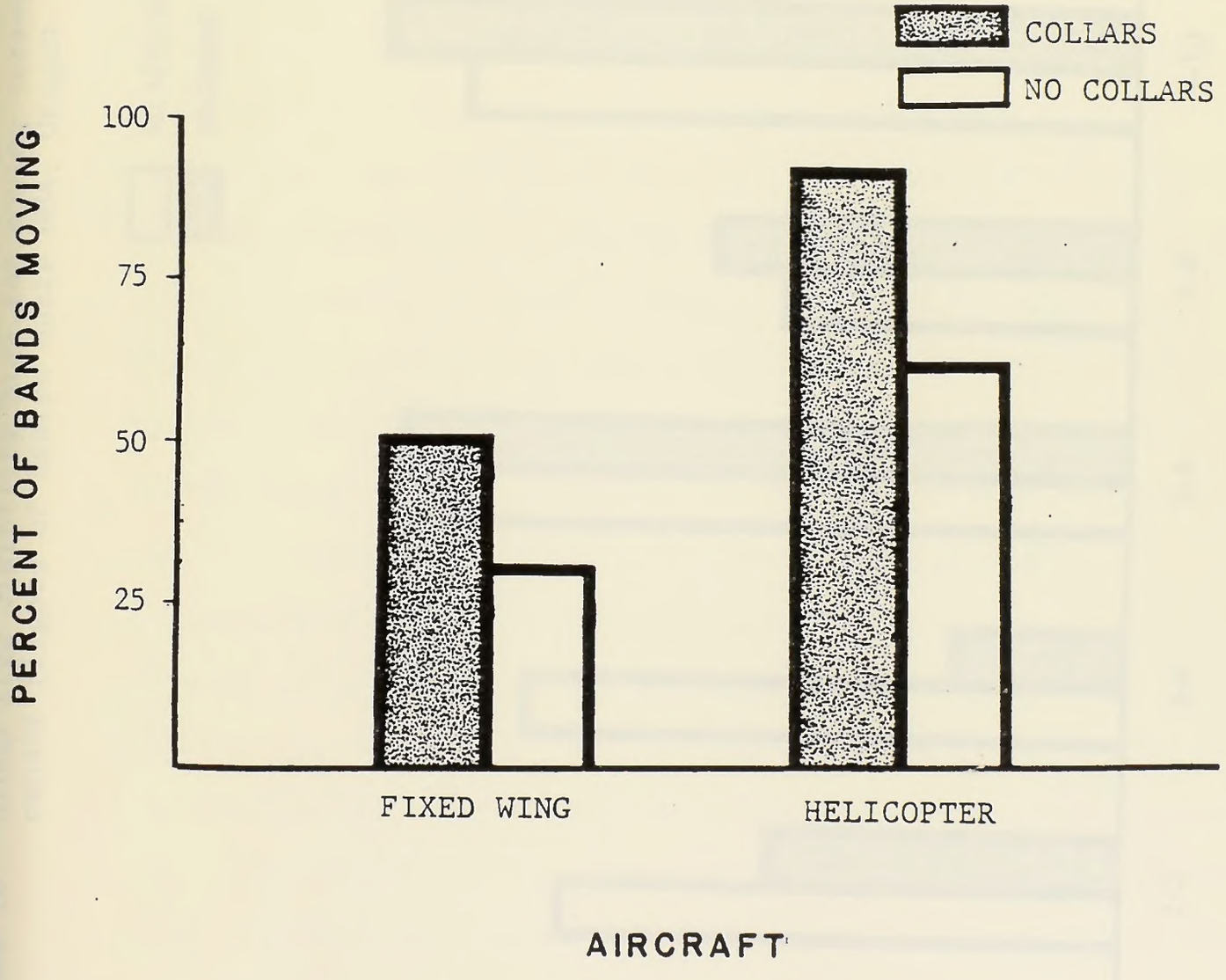
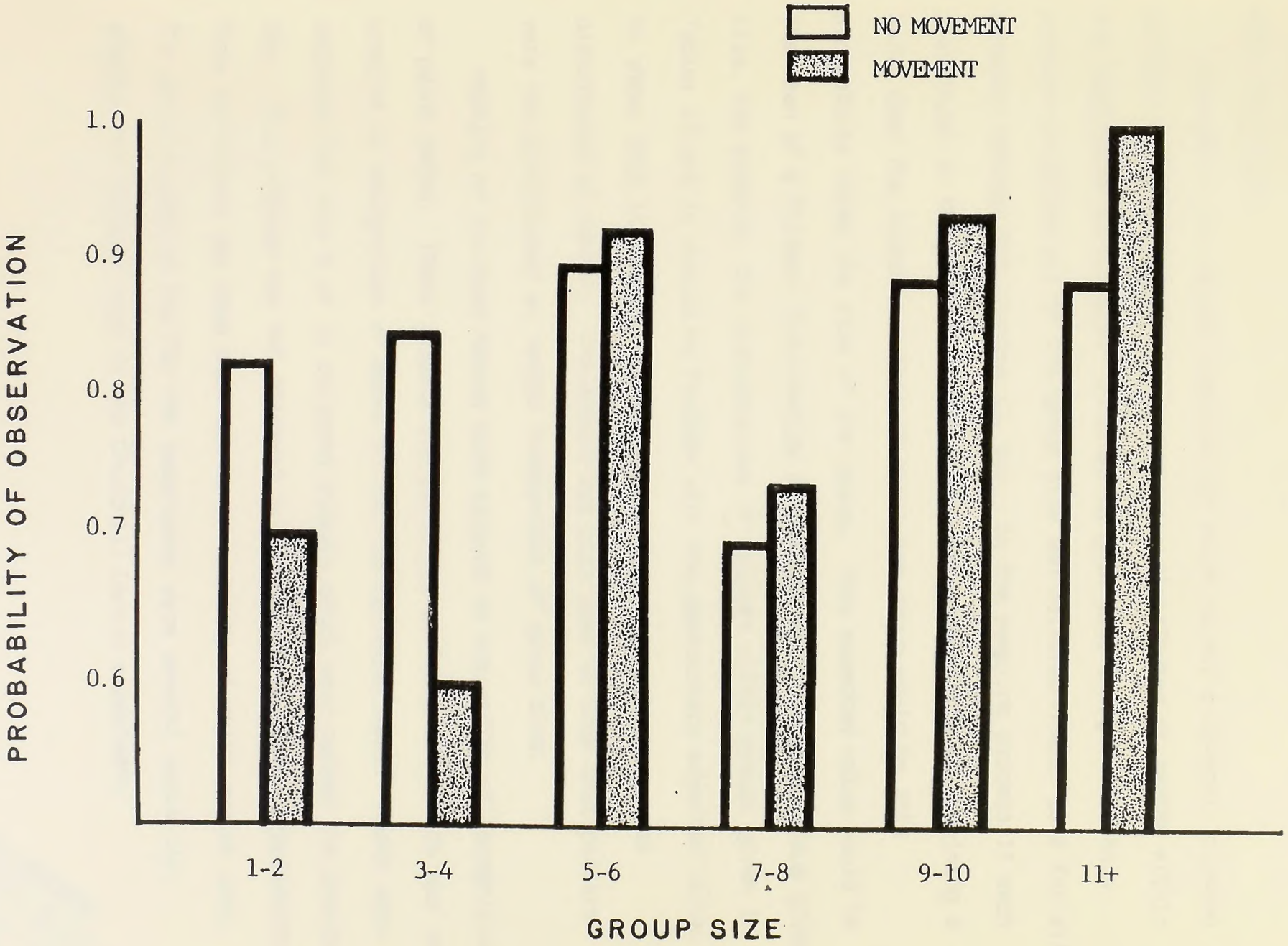


Figure 16. Group size visibility bias for moving versus non-moving groups on census flights of Beatys Butte HMA, Oregon.



effect appears to be related to topography and vegetative cover of the area considered.

Because of the social organization which causes a severely clumped pattern it is unlikely that our marks are distributed at random within the population as a whole. In order to gain some insight into this problem we pooled all of the group size and collared number data for all censuses during 1981 (Tables 13, 14). In the sampling process if each individual in the population has some equal probability of obtaining a mark, then the expected number of marks per group would be this probability times the size of the group. This expected value would be the mean of a Poisson distribution of collars within a given group given size. For example, the distributions of collars within groups given in Tables 13 and 14 should be Poisson with the appropriate expected value. As shown this is clearly not the case; thus, our collars are not distributed at random. Chi-square was also used to show that collars were not distributed at random independent of group size.

Marking of collared horses also allowed an evaluation of recognition of paint marks. These results are presented in Table 15. There was some problem in recognition of marks on the Pah Rah experiment. Marks were recorded for only 9 of 11 collared animals which were marked the previous day. This problem was not observed in the Churchill Canyon experiments. This difference may have been due to the quality of paint pellet used. The pellets used in the Pah Rah experiment were several years old, whereas the pellets used in the Churchill Canyon experiment

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Table 13. Number of collars observed in various size groups during census flights on Pah Rah Mustang Area, Nevada. Observations were made during helicopter flights on 5 May 1981, 3, 7, 8 July 1981 and 7 Sept. 1981.

	GROUP SIZE														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
0	27	32	48	62	32	44	36	42	28	32	28	19	13	12	27
1	3	4	12	9	12	17	11	4	4	2	6	7	2	0	6
2	-	0	3	3	6	4	2	4	6	1	4	2	0	0	9
NUMBER OF COLLARS 3	-	-	0	2	6	5	2	4	2	1	3	2	1	1	5
4	-	-	-	0	0	6	1	0	1	0	1	0	1	1	6
5	-	-	-	-	0	0	0	0	0	0	1	1	0	1	5
6	-	-	-	-	-	0	0	0	0	0	0	0	0	0	6
7	-	-	-	-	-	-	0	0	0	0	0	0	0	0	1
8	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0
9	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0
10	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0
TOTALS	30	36	63	76	56	76	52	54	41	36	43	31	17	15	65

Table 14. Number of collars observed in various size groups during census flights on Pine Nut Mountains, Nevada. Observations were made during helicopter flights on 7 May 1981, 1, 2-3, 21 July 1981 and 3, 4, 8, 9, 10, 11 Sept. 1981.

	GROUP SIZE														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
0	25	36	46	66	39	52	39	09	8	10	4	2	0	1	0
1	2	8	7	11	1	1	2	2	0	0	0	1	0	0	0
2	-	6	5	3	8	2	0	0	0	0	0	0	0	0	0
NUMBER 3	-	-	4	10	7	3	5	0	0	0	0	0	0	0	0
OF COLLARS 4	-	-	-	2	3	3	5	3	0	0	0	0	0	0	0
5	-	-	-	-	0	1	1	0	0	0	0	0	0	0	0
6	-	-	-	-	-	0	5	0	2	0	0	1	0	0	0
7	-	-	-	-	-	-	0	4	0	0	0	0	0	0	0
8	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0
9	-	-	-	-	-	-	-	-	0	1	0	0	0	0	0
10	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0
TOTALS	27	50	62	92	58	62	57	18	10	11	4	4	0	1	0

were newer. Casual observations indicated the the newer pellets left a bigger mark.

Another problem with paint marking was also observed during these trials. While marking animals in the Churchill Canyon area it was noticed that an unmarked animal received a mark by brushing against a newly marked animal. Later in the experiment, a collared animal that had not been marked was observed with a paint mark.

The utility of various types of aircraft can be evaluated by comparing census results on the Pah Rah Mustang Area and Pine Nut Mountains. Results for Piper Super Cub versus B-2 helicopter censuses on those areas were not significantly different. The Cessna 180 flight on the Pine Nuts produced a smaller total count than any of the other flights. This was not the case on the Pah Rah. It was noted during the Cessna 180 flights, however, that it was much more difficult to obtain accurate total and foal counts once a group had been located. This was due to the higher minimum altitude and faster speed of the Cessna 180.

A analysis was made to assess the costs involved in utilizing the B-2 helicopter, Cessna 180, Piper Super Cub, and Cessna 206 on various census flights (Table 16). For the Pah Rah Mustang Area, a 13% increase in the number of horses counted by using a B-2 helicopter versus a Piper Super Cub was accompanied by a 3 fold increase in costs. On the Pine Nuts, a similar increase in number of horses counted was observed, but costs of using a helicopter were almost 5 times that of using a Piper Super Cub. As has been noted, double counting is likely to be more of a problem with helicopter censuses. Part of the increase in mean total number of horses

Table 15. Recognition of paint marks on collared horses during mark-resight censusing of wild horses in Nevada 1981.

Area	Date	Color	Number of collared horses marked	Number resighted	Marks recognized	Observations of unmarked collared horses	Additional Marks*
Pah Rah Mustang Area	7-8 July	Orange	11	11	9	45	1
Pine Nut HMA	8-11 Sept	Orange	7	7	7		
		Green	14	10	10	63	1
		Yellow	10	4	4		
	Totals		42	32	30	108	2

* These horses acquired "marks" by brushing against a newly marked horse.

Table 16. Cost analysis for various types of aircraft used for censusing. Actual hours of flight time was used for comparisons for Pah Rah Mustang Area and Pine Nut HMA. Chain Lakes HMA comparisons are based on estimated flight times. Costs for aircraft were as follows: B-1 Helicopter $200/hr, Cessna 180 $80/hr, Piper Super Cub $60/hr., Cessna 206-210 $125/hr.

Area	Aircraft type	Number of flights	Mean hours	Mean total count	Average cost (in dollars)
Pah Rah Mustang Area	Cessna 180	1	2.5	422	200
	Piper Super Cub	5	6.3	412	378
	B-2 Helicopter	5	5.5	472	1100
Pine Nut HMA	Cessna 180	1	5.5	193	440
	Piper Super Cub	1	9.0	295	540
	B-2 Helicopter	3	12.9	336	2580
Chain Lakes HMA	Cessna 180	EST.	9.9	-	792
	Piper Super Cub	EST.	13.2	-	792
	B-2 Helicopter	EST.	11.4	-	2282
	Cessna 206/210	2	6.6	-	825

counted could simply be due to double counting instead of any real increase in effectiveness.

For the Chain Lakes Herd Area, a comparison could only be made of the estimated number of hours needed by various types of aircraft. It is assumed here that since little visibility bias was observed using a Cessna 206 or 210 that counts with slower aircraft would produce similar total count results. BLM's current use of a Cessna 206 is probably the most effective for this area.

Relationship of Band Sizes to Population Density

A strong correlation was noted for observed mean band sizes and population density for past fall census on Beatys Butte. Figure 17 shows this relationship of increasing mean band size with increasing population density. The outlier was a year when it appeared that many bands were combined at the time the count was made.

Band sizes observed prior to and following the February 1981 gathering of horses on Beatys Butte also reflected this. Mean band size before the gathering was 7.1. Following the gathering, mean band size dropped to 4.4 (Figure 18). Although these values are both less than those predicted by the regression equation, it is possible that seasonal changes in band size may be responsible for this difference.

Strip-Transect Estimation

A graph of coefficients of variation for levels of sampling intensity ranging from 5% to 95% is shown in Figure 19. Coefficients ranged from

Figure 17. Linear regression of mean group size on population density for 1971-1980 census data for Beatys Butte HMA, Oregon. A significant positive relationship ($p<0.01$) was found.

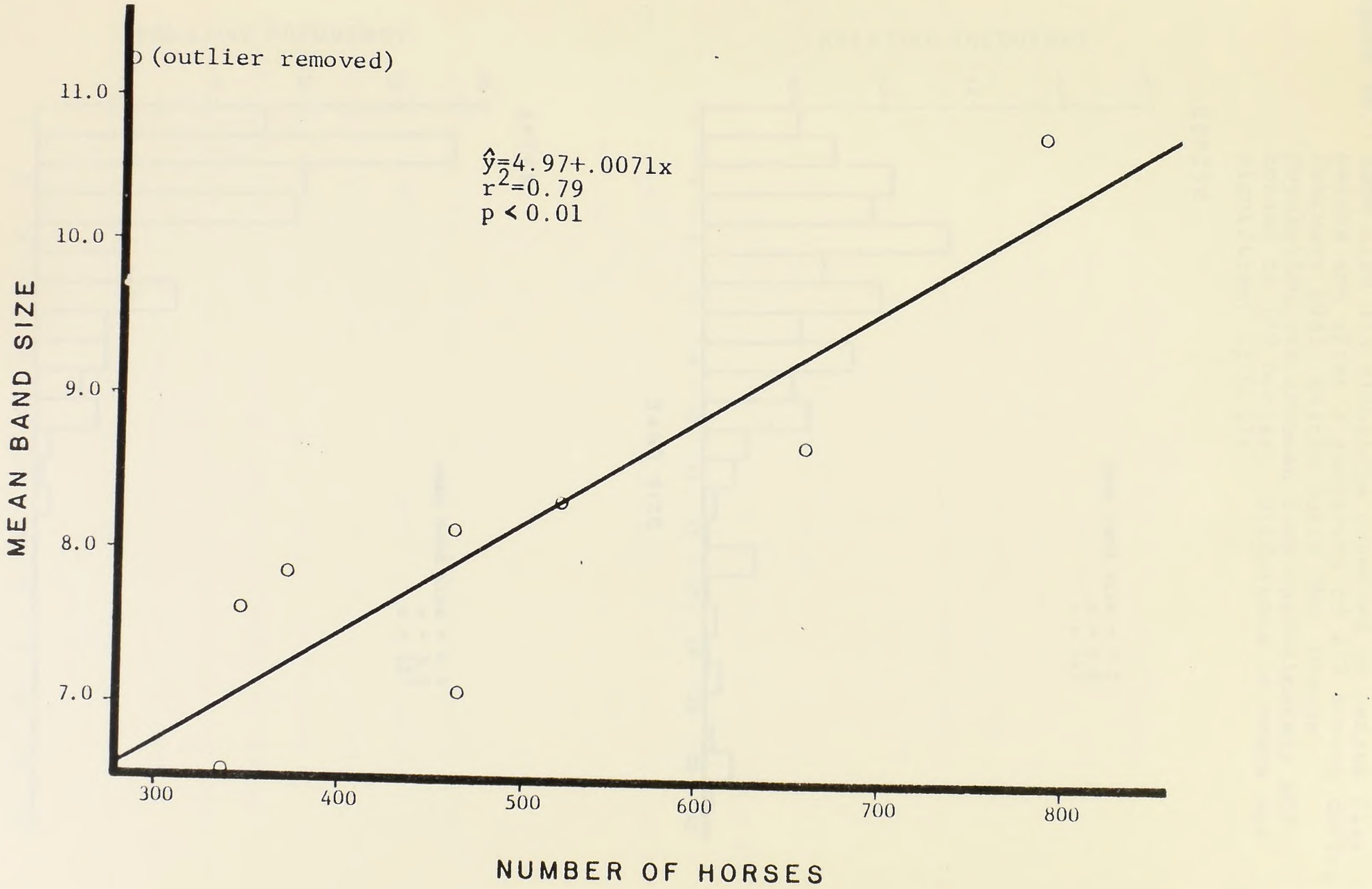
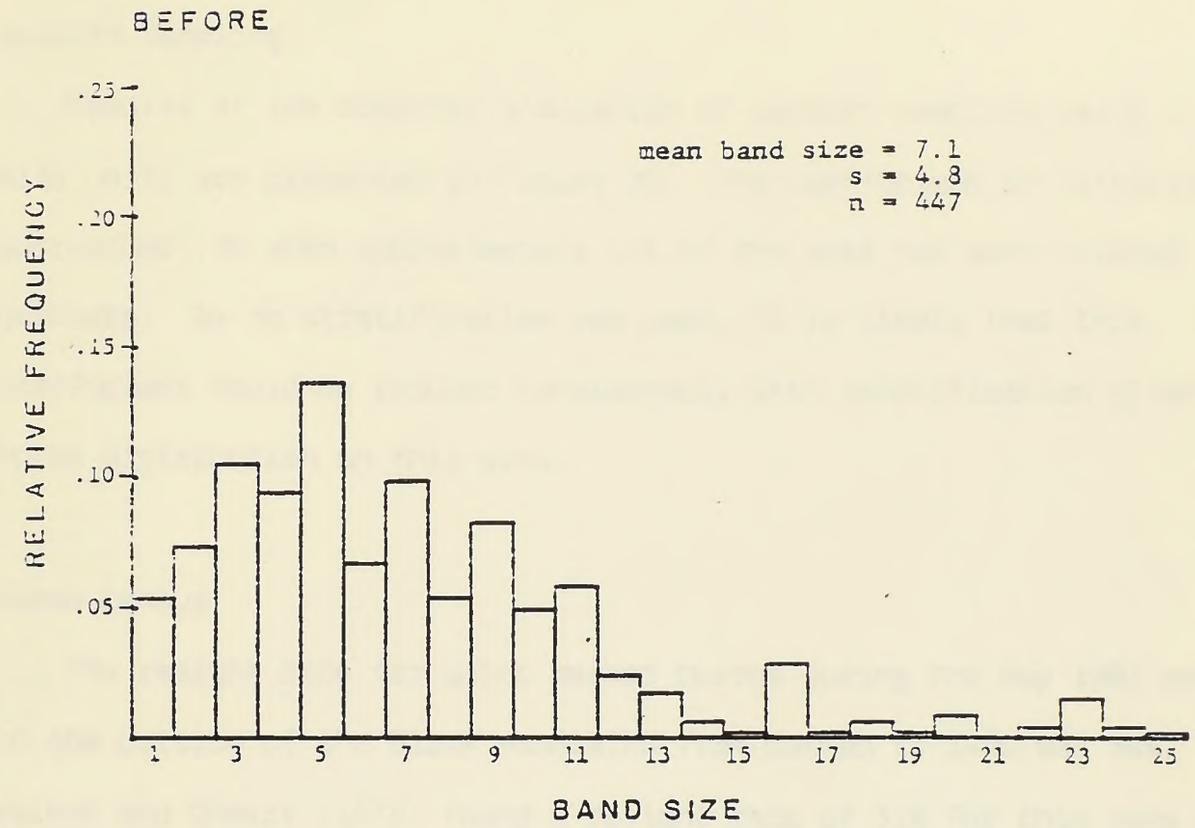
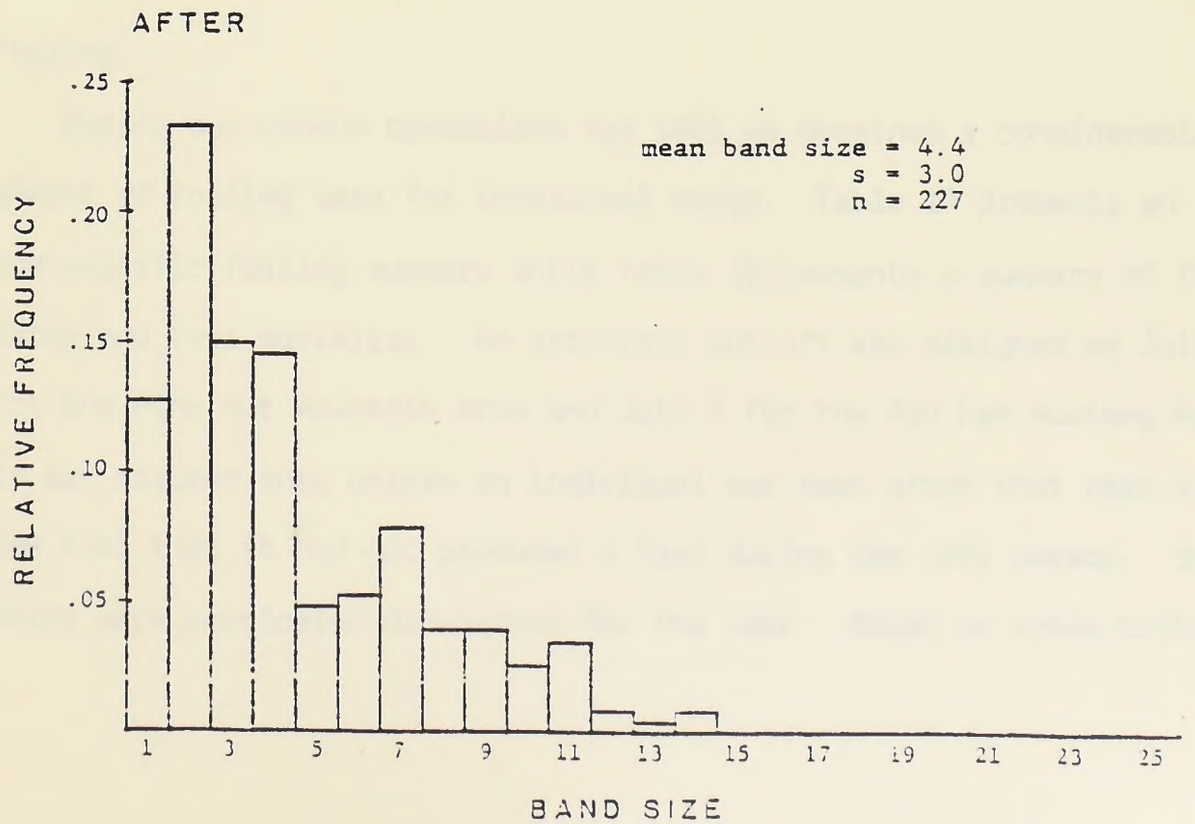


Figure 18. Band size distributions observed on census flights before and after a gathering of 272 horses during February 1981, Beatys Butte HMA, Oregon. Population was reduced from approximately 425 horses to 150 horses. Difference in means was significant ($p<0.01$).





1.213 at a 5% level of intensity to 0.0649 at a 95% level of intensity.

Quadrat Sampling

Results of the computer simulation of quadrat sampling using 1 square mile units are presented in Figure 20. The coefficient of variation approached .25 when approximately 1/4 of the area had been covered by quadrats. As no stratification was used, it is likely that this coefficient could be reduced considerably with stratification given the horse distribution on this area.

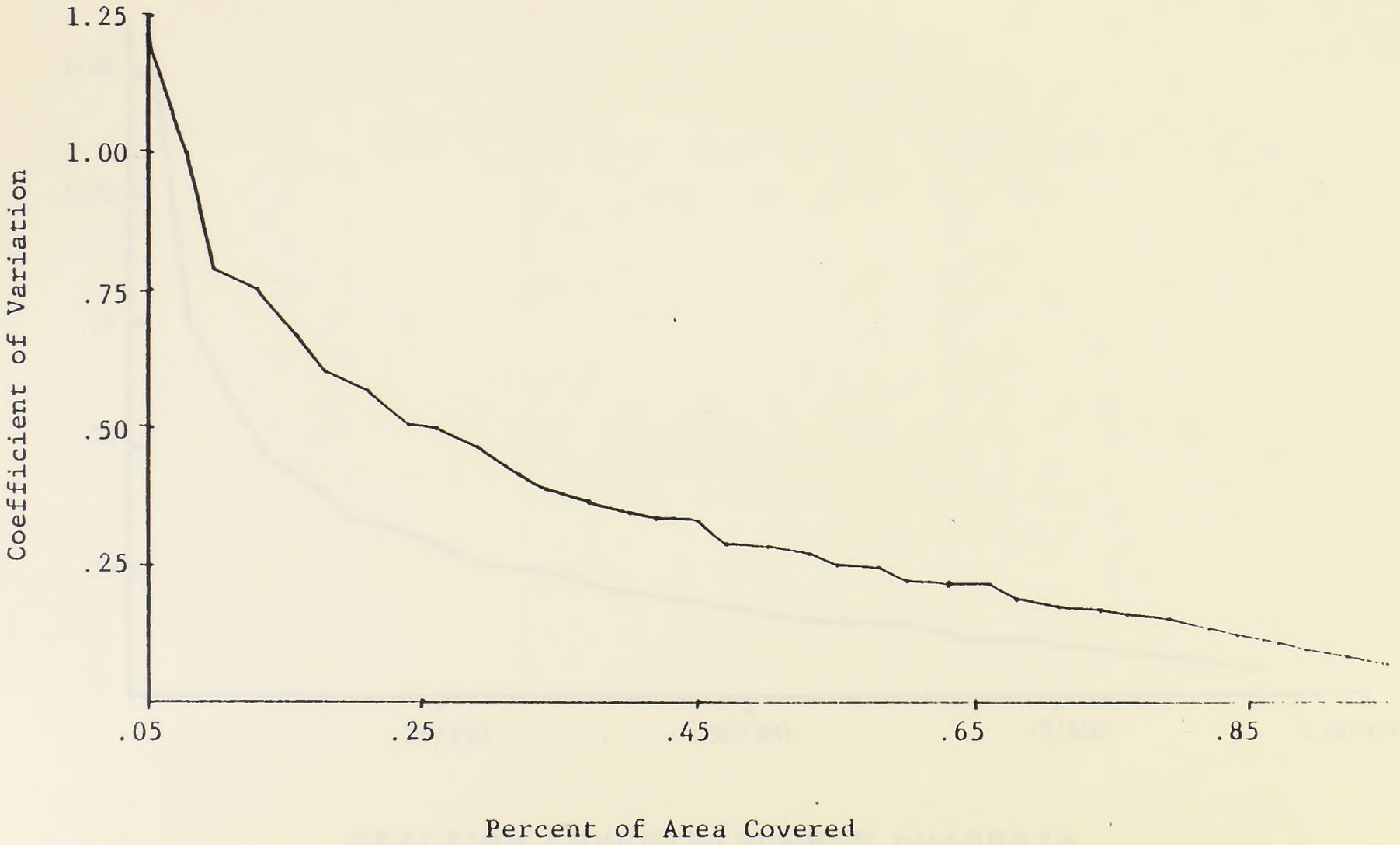
Burro Census

The resight rate for paint marked burros during the May 1981 census on the portion of the Black Mountains from Oatman to I-40 was 54%. Walker and Ohmart (1978) found a resight rate of 51% for this same area in September 1977.

Foaling

During our census operations for 1981 we obtained a considerable amount of foaling data for individual mares. Table 17 presents an age-sepcific foaling summary while Table 18 presents a summary of foaling rates and foal mortality. An arbitrary cut off was assigned as July 2 for the Pine Nut Mountain Area and July 3 for the Pah Rah Mustang Area. It was assumed that unless an individual was seen after that date with a new foal that it had not produced a foal during the 1981 season. Such mares were considered non-parous for the year. Based on these criteria,

Figure 19. Graph of coefficient of variation for various levels of sampling intensity for simulated strip-census flights of Pah Rah Mustang Area. Sampling intensity is represented by the proportion of area covered during census flight. Coefficents were determined from 1000 simulated flights at each level of intensity. Wild horse population and distribution data from 5 May 1981 helicopter census provided theoretical population.



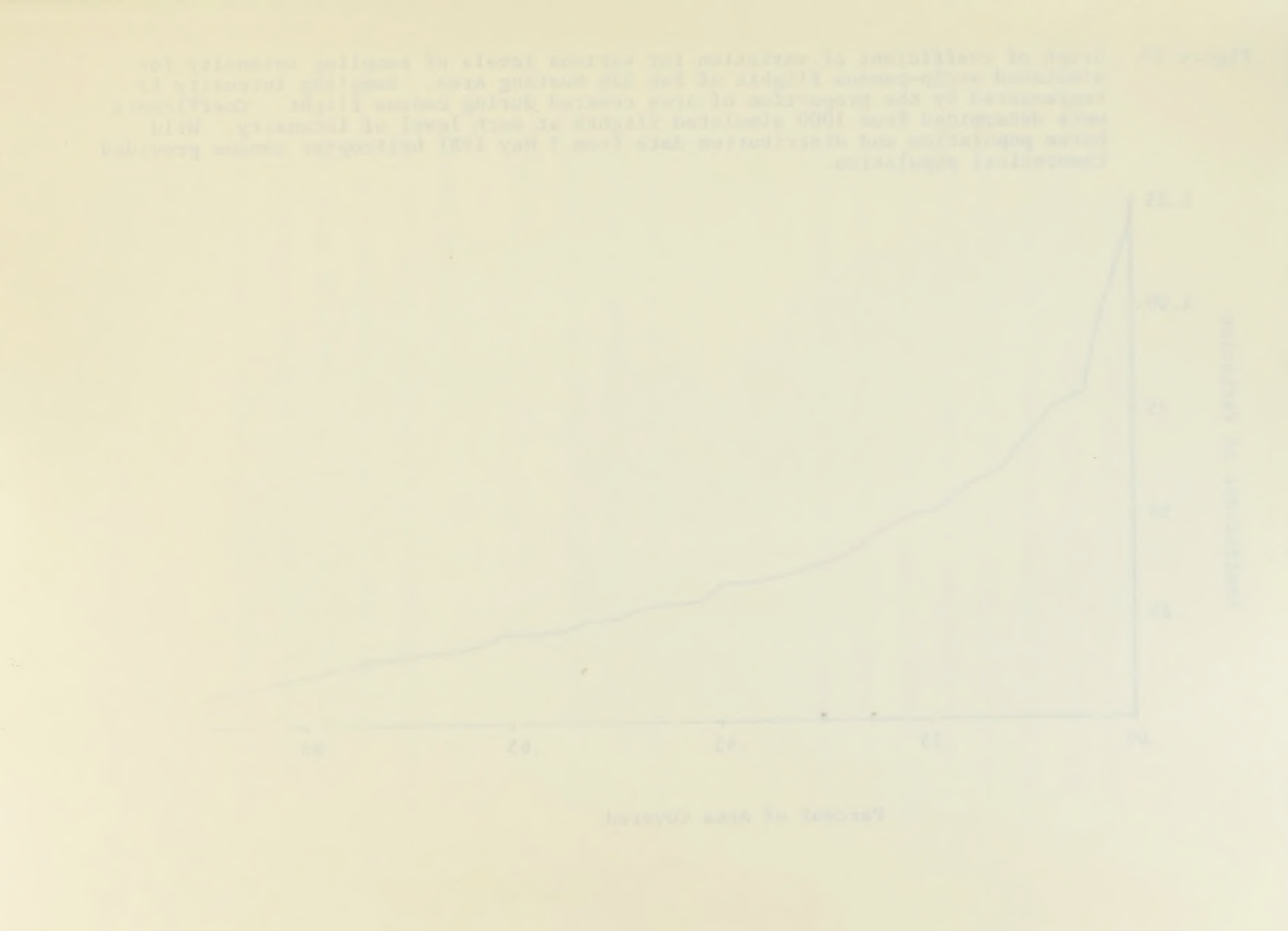


Figure 20. Graph of coefficent of variation for various levels of sampling intensity for simulated quadrat sampling of Pine Nut Mountains Herd Management Area. Coefficients were determined from 1000 simulated flights at each level of intensity.

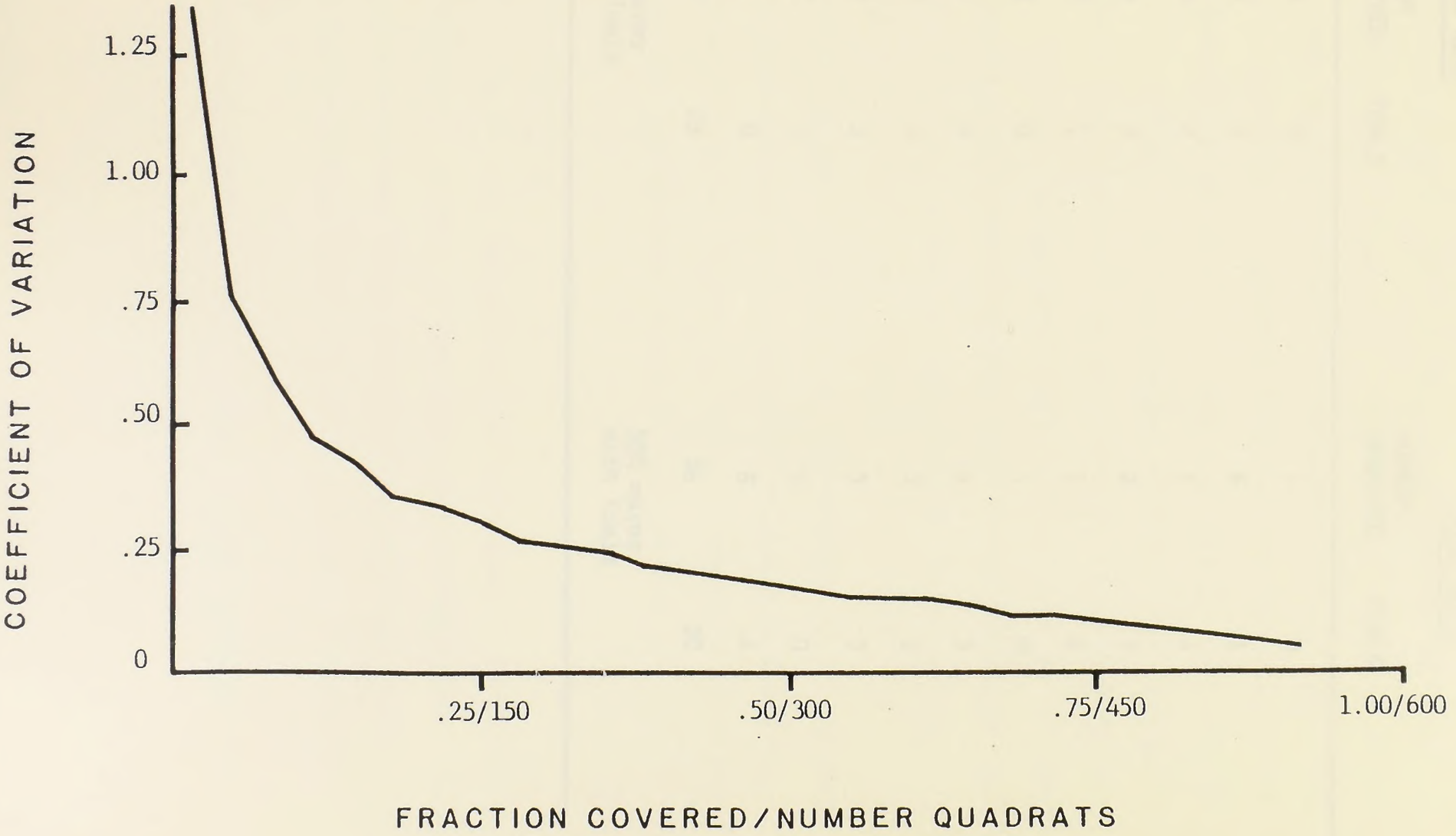


Table 17. Overall foaling summary for collared females

	PAH RAHS		PINE NUTS	
AGE CLASS	NUMBER OBSERVED	FOALS	NUMBER OBSERVED	FOALS
2	0	0	1	0
3	5	2	6	1
4	8	4	6	4
5	4	4	2	1
6	3	1	2	2
7	0	0	1	0
8	6	4	4	3
9	7	6	3	2
10	3	3	3	3
11	2	1	0	0
12+	1	0	8	4
Totals	39	25	36	20
	61% mares with foals		55% mares with foals	

foaling rates for the two areas are quite comparable.

Foal mortality is significantly higher for the Pah Rah district Area, however. The reason for this high mortality remains unknown at this time, but it is of interest to consider further when the majority of the mortality occurred. By partitioning the 3 census periods of May 5, July 3 and Sept. 7, we found that of the foals born prior to May 5, none were identified as having died in the interval May 5 to July 3. However, the period from July 3 to Sept. 7 was considerably different. We were able to determine that 9 foals were born in this interval, of which 6 died in this interval. These data suggest that foals born early in the year have a better chance of survival than those born late. A similar analysis was not possible for the Pine Nut Mountain Area since so few mortalities occurred there.

Observations of foaling are continuing. The addition of 73 collared females will increase the amount of information available considerably. The age distribtuion of marked females by age is presented in Table 19. Ages of 3 horses have not yet been determined from photos.

Chemical Immobilization

A total of 91 horses were immobilized from helicopters. Of these, 73 were equipped with radio collars, 13 were males and 5 animals died. A total of 141 darts were fired for an average of 1.6 darts per horse. An average of 48 minutes of helicopter time was used to down and process each animal.

A 6% loss rate was observed. These losses included 2 animals with

Table 18. Foaling rates and foal mortality of collared mares.

	PINE NUTS	PAH RAHS
Dates:	7 May - 21 July	5 May - 7 Sept.
Mares:	36	39
Foals:	20	25
Foaling Rate:	.55	.61
Foal Mortalities	3	8
Foal Mortality Rate:	.15	.33

Table 19. Collared mares available (Spring 1982) for foaling observations on Pah Rah Mustang Area and Pine Nut Mountains.

	PAH RAH MUSTANG AREA		PINE NUT MOUNTAINS		
AGE	RADIO	COLOR	RADIO	COLOR	TOTAL
2	3	-	-	-	3
3	7	-	-	1	8
4	8	2	6	2	18
5	11	2	7	1	21
6	4	1	6	1	12
7	3	-	7	2	12
8	2	2	3	1	8
9	4	5	5	2	16
10	9	1	6	3	19
11	3	5	6	2	16
12+	10	3	7	2	22
UNDETERMINED	2	-	1	-	3
TOTALS	66	21	54	17	158

broken legs that were euthanized, 1 animal that abruptly died while being processed, 1 animal that received facial and neck cuts when it ran through a fence when it was first immobilized and was unintentionally immobilized again on the next day, and one animal that was unable to get up on it's feet following immobilization, possibly due to a broken leg.

Mean drug induction time was 11.6 minutes (Figure 21). The induction time is defined as the amount of time elapsing from when an animal is shot with a dart until it goes down. The recovery times observed are summarized in Figure 22. This is the amount of time elapsing from injection of the antidote until the animal is on its feet. The mean time was 66 seconds. Animals that had a recovery time longer than 3 minutes had either problems in getting on their feet because of terrain or remained down longer because the antidote had been given intramuscularly instead of intravenously. The cost breakdown for the immobilizing procedures is given in Table 20.

Figure 21. Induction time for wild horses injected with a combination of 5.5mg etorphine, 150 mg xylazine, and 3 mg atrophine on Pah Rah Mustang Area and Pine Nut Mountains, Nevada during December 1980 and February 1981.

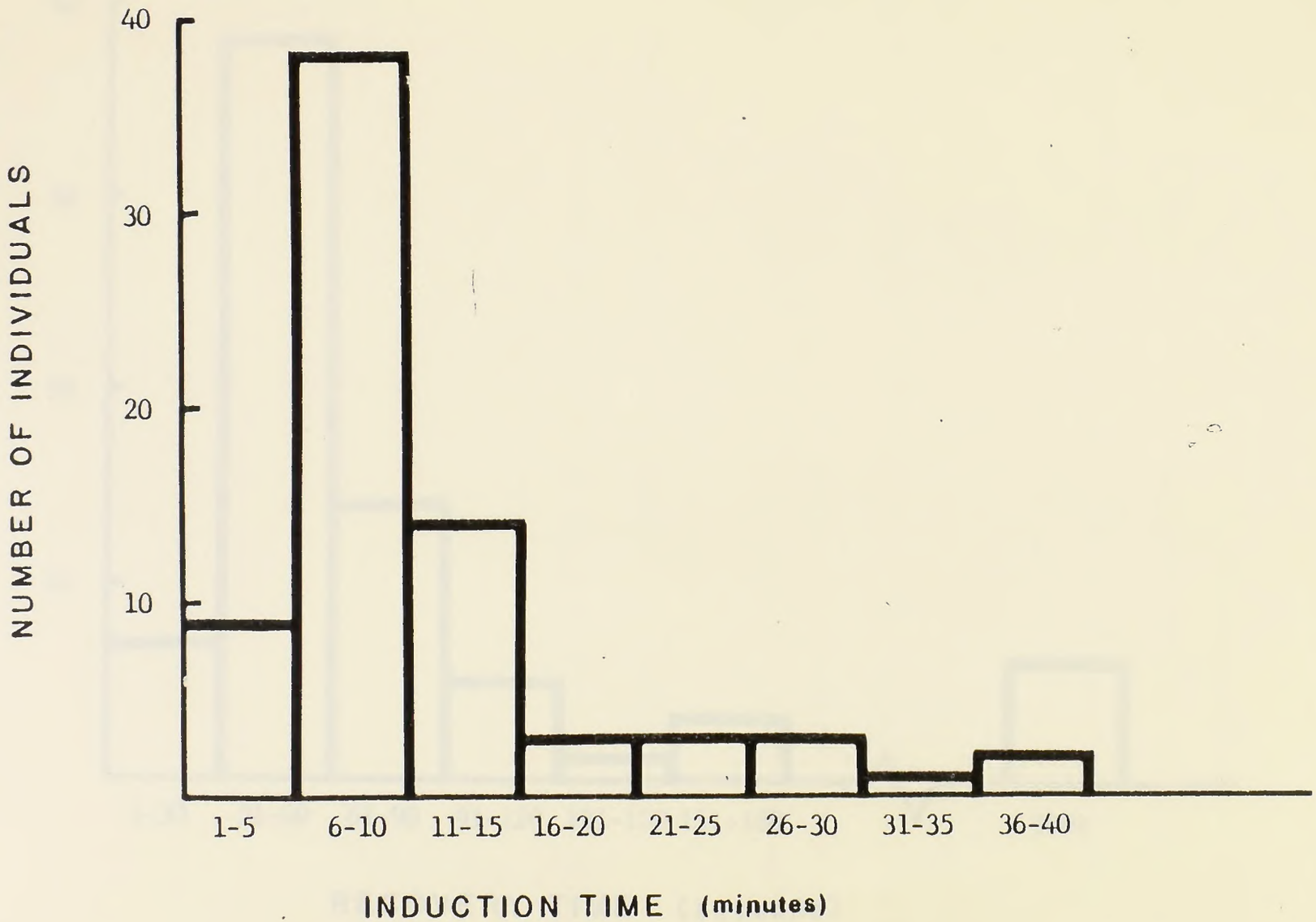


Figure 22. Recovery time for wild horses given standard doses of 11.0 mg diprenorphine hydrochloride following immobilization with standard drug combination. Recovery time is the elapsed time from injection of antidote until the horse is on its feet.

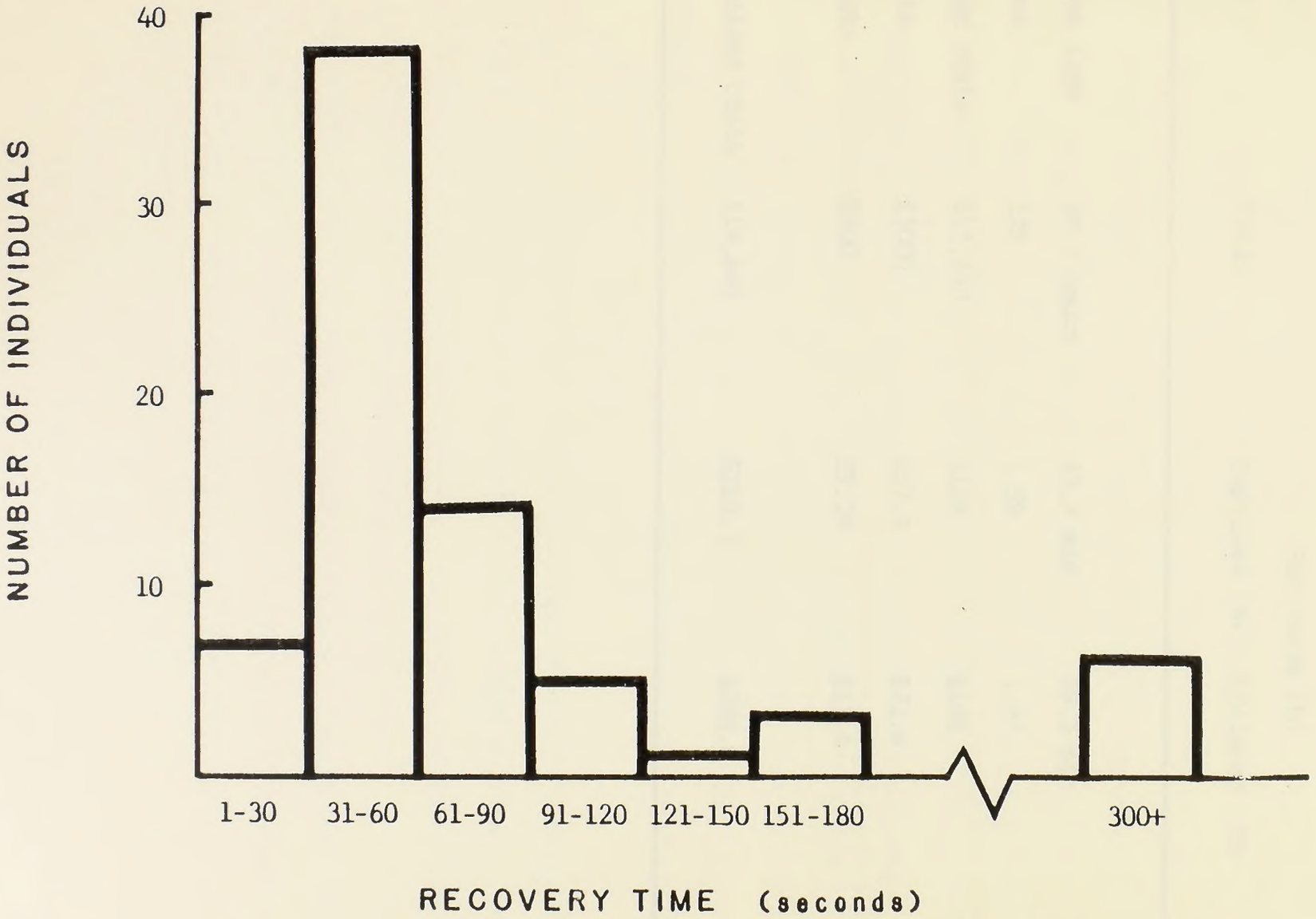


Table 20. Helicopter and supply costs for drug-immobilization of 87 free-ranging feral horses from helicopters.

Variable	Total	Per Horse (N) Captured (87)	Collared (70)
Helicopter time	69.2 hours	47.7 min	59.3 min
Darts shot	138	1.59	1.97
Helicopter costs	$13,840	$159	$198
Drug costs	$5000	$57.5	$71.4
Darts lost	$800	$9.20	$11.4
Sum of dollar costs	$19,640	$225.7	$280.8

DISCUSSION

Accuracy of Total Counts

Areas with relatively flat terrain and no tree cover present little problem as far as census accuracy. The fact that, on the average, 93% of the horses were tallied on census flights on Beatys Butte indicates that fixed wing censusing in this type of habitat is probably adequate for obtaining population estimates on which to base management decisions. Any increase in accuracy that might be provided by using a helicopter would be slight at a much greater cost. A helicopter census could even conceivably be less accurate given the problem of double counting. The biggest problem in these areas is emmigration and immigration in open populations. This is evidently what has been happening in the Chain Lakes Herd Area. The history of counts shows fluctuations that can only be due to inadequate coverage of the area or movement of animals. In such areas methods to assess such movement need to be part of census designs.

Results from surveys of Pah Rah Mustang Area and Pine Nut Mountains indicate that a substantial number of horses can be missed on total count surveys of areas with rough topography and/or tree cover. At this time it appears that replicate counts using the Lincoln-Peterson mark-recapture method give the most reliable estimates of population size on these areas. The Jolly-Seber or multiple mark-recapture techniques do not seem to be an improvement over simple replicates of the Lincoln-Peterson estimates.

The problem of the distribution of tags over a clumped population clearly needs attention. It seems likely that a major source of variation for the estimation techniques which we have used may come from this problem. The difference of probability of sighting because of group size enters as a bias, but also the problem of distributing tags at random within a clumped population needs to be considered. The use of marked bands as a basis of estimation may be desireable. Of course, this type of analysis involves obtaining some estimate of band integrity, which may vary from area to area. Integrity may be high where range conditions are good and competition for forage is not a primary motive for movements and interaction. In addition, season of the year and breeding activity no doubt cause shifts in band sizes and composition. Because of these factors it may be that the problem of random marking is something that is virtually impossible to solve for species which are as severely clumped as horses. The exact statistical procedures which apply in this case also remain unclear. Further examination is needed with respect to theoretical corrections that may be possible given data on group size as well as distribution of marks.

Paint marking may provide a means of correcting total counts but suffers from the same sorts of problems with differing group sizes as was discussed for mark-resight estimates based on collar resights. Most of the technical problems are not insurmountable.

The calibration of an index by removal method appears to be a relatively inexpensive approach by which a further check on the accuracy of a census count can be obtained. This method assumes that the same

proportion of the population is counted before and after the removal. This report has presented information that suggests this may not be a valid assumption. Results from Beatys Butte indicated that the distribution of group sizes is altered by a gathering, skewing the distribution toward smaller groups. Results were also presented that indicated smaller groups (less than 5) had a lower probability of observation than larger groups. This bias would result in an underestimate of the true population size.

It appears that unless a marking operation is being conducted, a Piper Super Cub will provide comparable census results for a fraction of what it would cost to census an area with a helicopter. A considerable savings could be realized if this type of aircraft was used for routine census flights. It must also be remembered that a Piper Super Cub has manuverability and speed characteristics that are far superior for rugged terrain as compared to most other fixed wing aircraft.

Variables Affecting Accuracy

The fact that smaller bands are less likely to be seen than larger bands is hardly surprising. It does however, emphasize the point that the probability of counting all horses during a total count census is extremely remote.

Snow cover can significantly influence the outcome of a total count. Censuses should be conducted only under snow free conditions. At the very least, accurate recording of snow conditions is an absolute necessity. The snow that was present on Beatys Butte was not very deep.

It left sagebrush very visible creating a mottled or splotchy background from which it was hard to distinguish horses. The only possible case where snow cover may improve observability could occur if the snow cover was deep enough to cover the sagebrush entirely. This would be a rare occurance in most areas given the height of sagebrush and the typical winter weather pattern.

Cloud cover effects were not clear cut. Direct sunlight appears to aid in spotting smaller sized bands. For larger sized bands it evidently is not as critical.

The fact that there was no fatigue effect in spotting smaller bands was surprising. Flights on Beatys Butte were long in duration, lasting from 4 to 6 hours without any breaks. We expected fatigue to show up in the second half of the flight with decreased probabilities of observation for all band sizes. This turned out to be true only for larger bands. It appears that practice in spotting small bands contributed more to the overall observability for small bands than did fatigue. This was not the case for larger bands where practice evidently contributed little.

Observer experience was not demonstrated to play a major role in influencing total counts. It is important to distinguish between these results and the resuts of Frie et al. (1979). They compared 3 observers reported to have had 900, 150 and 0 hours of census experience. The observers with previous census experience were both familiar with their study areas, the person with no censusing experience was not. Each observer had to determine his own flight pattern. If one re-examines their results, there was a significant difference in total counts only

between the observer who was not familiar with the area and the other 2 observers. There was no significant difference between the observer with 150 hours of experience and the observer with 900 hours of experience.

In this study, experience was evaluated only with regards to spotting horses. In one evaluation the observer had little censusing experience but was familiar with the area from the ground and could navigate the plane in a manner that ensured full coverage. In the other evaluations, flight pattern was not critical but and only the ability to spot horses was considered.

It appears that censusing experince is not critical as long as an observer is familiar with the area to be censused. Ground familiarization before a census may be advisable.

Double-counting has the potential to influence the outcome of a total count. In areas of high concentration of horses censusing can be difficult if horses are reacting to aircraft by moving. Because horses react less to a fixed wing aircraft than a helicopter, double counting should not be a significant problem in Oregon and Wyoming or in other areas where fixed wing aircraft are used. Besides the cost factor, this is another important consideration when deciding whether to use fixed wing aircraft or helicopters.

Alternative Methods to Total Counts

The relationship of mean band size to population density was examined to determine if mean band size could be useful as an index for population density. Although a strong relationship was evident in past census data

for Beatys Butte, the magnitude of change in mean band size compared to population density makes it doubtful that mean band size would be a practical index. A very large number of band sightings would have to be made to obtain reliable results from the predictions made by the regression line. Also, seasonal differences in mean band size must be further explored to account for changes unrelated to population density.

This initial evaluation of strip-transect censusing indicates that over 55% of the Pah Rah Area would have to be covered using strip-transects to provide reliable estimates. Because of the clumped distribution of the horse population, levels of sampling intensity less than this provide estimates that vary considerably from census to census.

At an intensity of sampling greater than 55%, any savings in aircraft censusing time over total counts would be greatly diminished. Also, the model used assumes 100% observability. Deviation from 100% will further reduce the utility of strip-transects.

Burro Censusing

It was interesting that resight rates were so similar between Walker and Ohmart's 1977 census and the recent census; 51% and 54%, respectively. If the resight rate for a given area remains relatively constant, marking could be dispensed with once a correction factor had been established. Then subsequent counts could simply be total counts adjusted by the correction factor. The savings in helicopter time and man-hours would be substantial.

Correction factors may vary seasonally due to changing probabilities

of observation related to changes in background vegetation. Cloud cover, flight altitude and search intensity are additional variables that need to be considered.

Several potential sources of error associated with the paint mark-resight method commonly used by BLM personnel need to be investigated. Paint marks need to be evaluated for observability. Marks lost to grooming and dusting behaviors need to be quantified. Effects of the initial marking on subsequent animal behavior need to be evaluated. The reaction of marked and unmarked animals to aircraft on resight flights must be determined. If these reactions differ, the effect on observability must be evaluated. Sighting rates may be different for different color burros which may be biasing mark resight estimates. The lack of sampling scheme when marking may also be affecting the accuracy of the mark resight estimates.

Foaling

The foaling rates which we obtained from actual observations are comparable to those reported in the literature (Boyd 1979, Welsh 1975, Nelson 1979). It seems likely that these values represent actual foaling rates in areas where range deterioration has occured to some degree. The high mortality rate for the Pah Rah during the late summer comes as a surprise and clearly further investigation through partitioning of mortality needs to be done. It seems logical that as the summer progresses, forage is likely to decrease in quantity and quality, particularly in areas where over-grazing seems to have occurred. Thus,

this would give the impression that there is a definite advantage for early foaling in most desert areas of the United States. If the mortality indicated for the Pah Rah district is at all typical, this points to a very high selective force which would tend to move foaling dates to earlier time frames and to synchronize reproduction.

Chemical Immobilization

The use of etorphine hydrochloride - xylazine hydrochloride - atropine in combination appears to be much more desirable immobilization agent than succinylcholine in terms of loss rates. Availability of an antidote vastly improves the success of this drug. Disadvantages are that it is expensive and is a controlled drug, requiring a veterinarian or other properly licensed offical for purchase.

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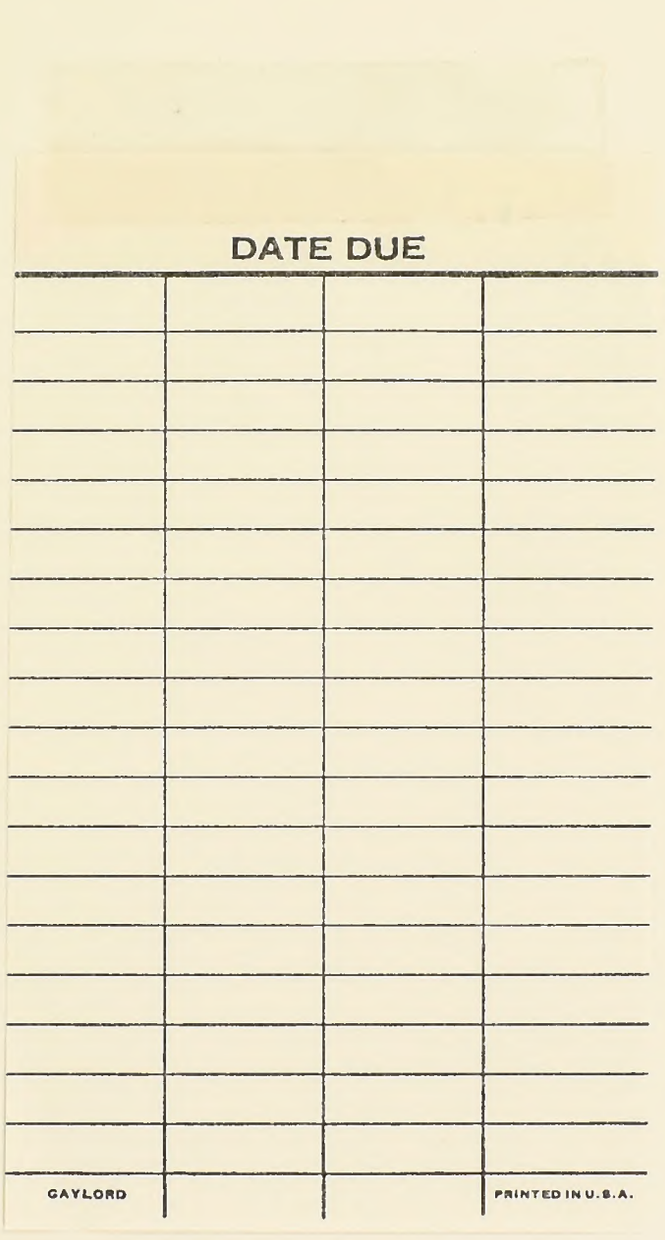

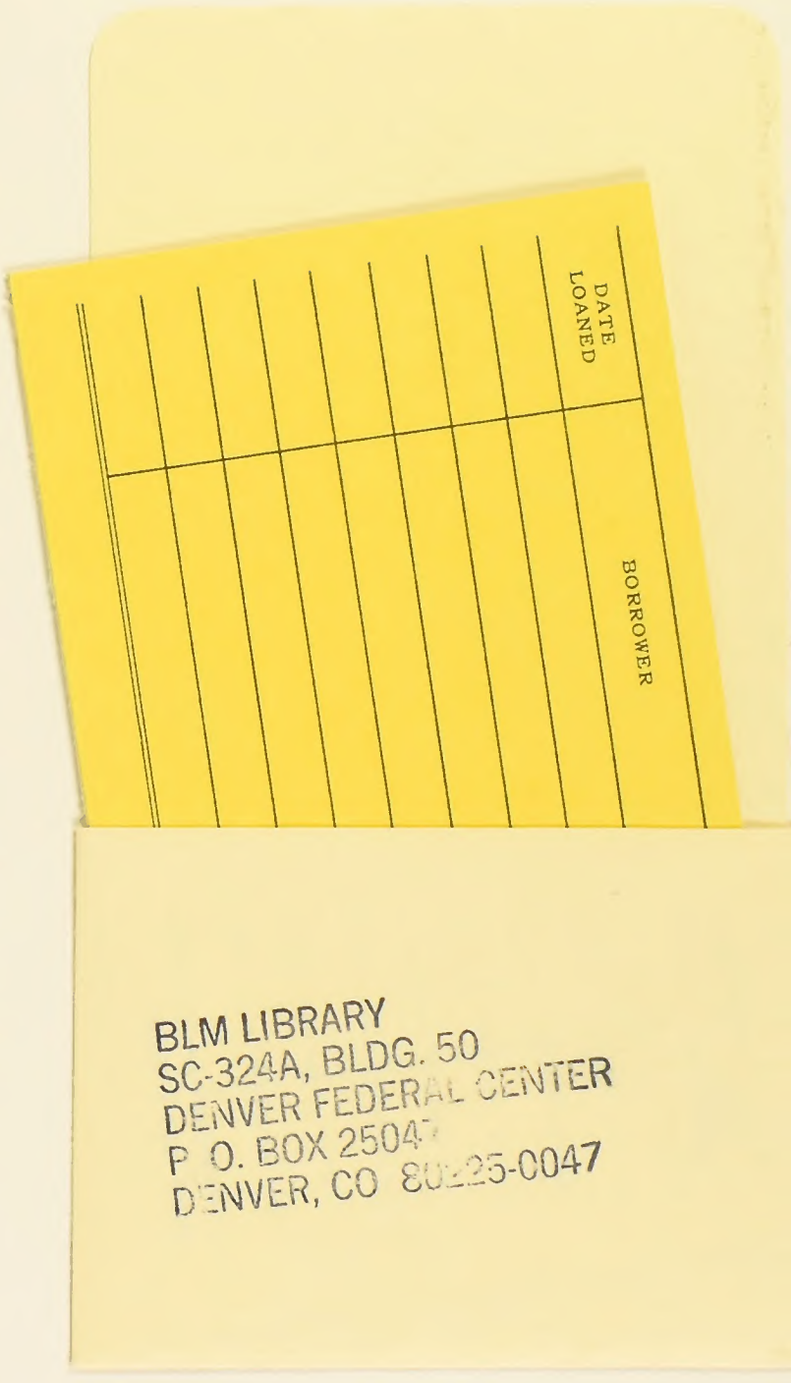

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